SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Sewage Colloids—Rudolfs and Balmat

Sewer Records—Stallings

Catalytic Oxidation of Wastes—Green and Moses

Instrumentation in Wastes Control—Greer

Stream Classes and Standards—Dappert

MARCH, 1952—VOL. 24, No. 3

Make Plans to Attend

SILVER ANNIVERSARY MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

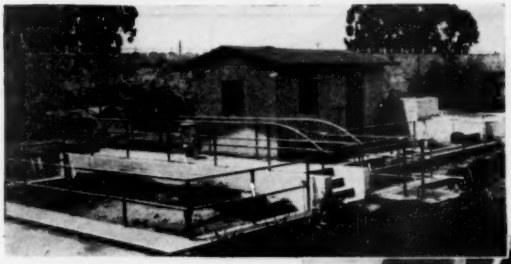
IN CONJUNCTION WITH

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

HOTEL STATLER
NEW YORK CITY

October 6-9, 1952

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS
325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS



Santa Barbara, California State Tuberculosis Hospital has a 'Pakage' Plant for complete and economical treatment of its sewage. This is one of over 250 such plants now in successful operation. Design flow is .1 M.G.D. R. W. O'Neill, Engineer.

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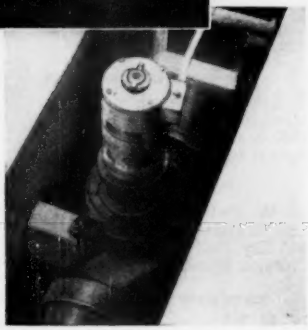

Greenwell Springs, Louisiana State Sanatarium has a comminutor to automatically screen and cut the solids at their 'Pakage' Sewage Treatment Plant. This is one of more than 2500 comminutors installed since 1934. State of Louisiana, Department of Institutions, Engineers.

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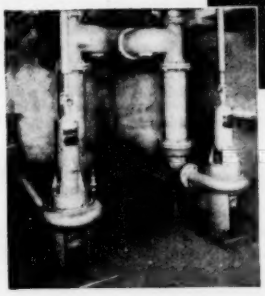

Braintree, Massachusetts, has a Flush-Kleen Sewage Lift Station, the only truly clog-proof pump for handling raw sewage or any liquid containing coarse stringy matter. This is one of over 5000 Flush-Kleen Lift Stations in daily trouble-free operation throughout the world. Samuel M. Ellsworth, Engineer.

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Prince and Lemon Sts., Lancaster, Pa.

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325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $5.00 per year.

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Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

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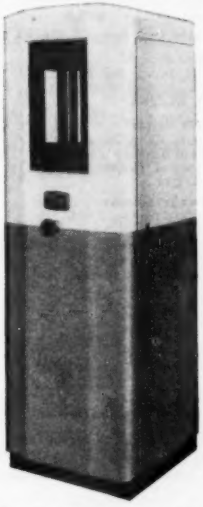

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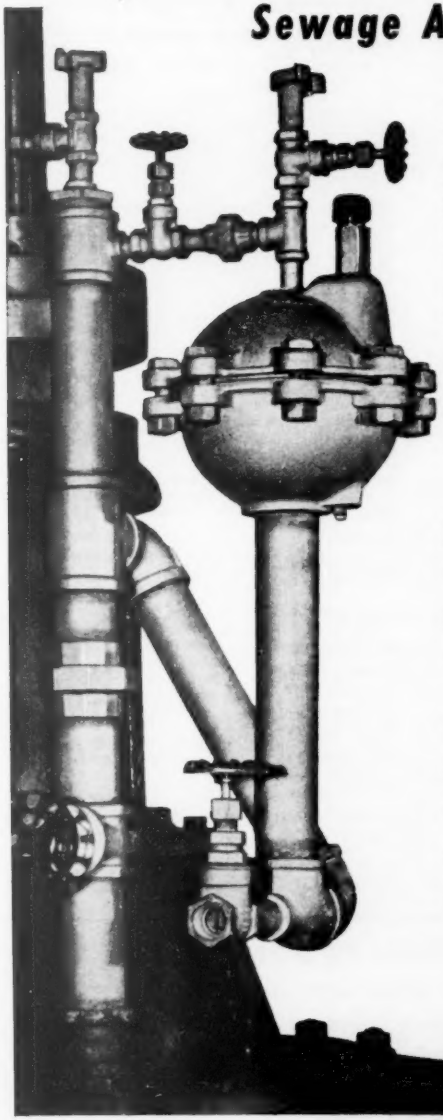

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Montana Sewage and Industrial Wastes Association	Northern Hotel, Billings, Mont.	April 10, 1952
South Carolina Water and Sewage Works Association	Clemson College, Spartansburg, S. C.	April 10–12, 1952
Maryland-Delaware Water and Sewerage Association	Wardman Park Hotel, Washington, D. C.	April 17–18, 1952
California Sewage Works Association	Casa Del Rey Hotel, Santa Cruz, Calif.	April 23–26, 1952
Virginia Industrial Wastes and Sewage Works Association	Hotel Roanoke, Roanoke, Va.	May 12–13, 1952
Michigan Sewage and Industrial Wastes Association	Park Place Hotel, Traverse City, Mich.	May 19–21, 1952
Ohio Sewage and Industrial Wastes Treatment Conference	Commodore-Perry Hotel, Toledo, Ohio	May 21–23, 1952
New England Sewage and Industrial Wastes Association	Hotel Elton, Waterbury, Conn.	May 22–23, 1952
Alabama Water and Sewage Assoc.	Pitts Hotel, Auburn, Ala.	June 4–6, 1952
Central States Sewage and Ind. Wastes Assn.	Loraine Hotel, Madison, Wisc.	June 25–27, 1952
Pennsylvania Sewage and Ind. Wastes Association	Pennsylvania State College, State College, Pa.	Aug. 27–29, 1952
Iowa Sewage Works Association	Grinnell College, Grinnell, Iowa	Sept. 9–11, 1952
Rocky Mt. Sewage Works Assn.	Frontier Hotel, Cheyenne, Wyo.	Sept. 15, 1952
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Johnson Hotel, Knoxville, Tenn.	Sept. 15–17, 1952
South Dakota Water and Sewage Works Conference	Marvin-Hughitt Hotel, Huron, So. Dakota	Sept. 17–19, 1952
Missouri Water and Sewerage Conference	Governor Hotel, Jefferson City, Mo.	Sept. 21–23, 1952

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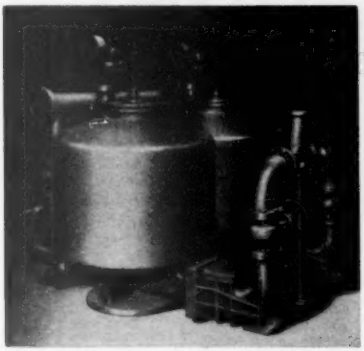

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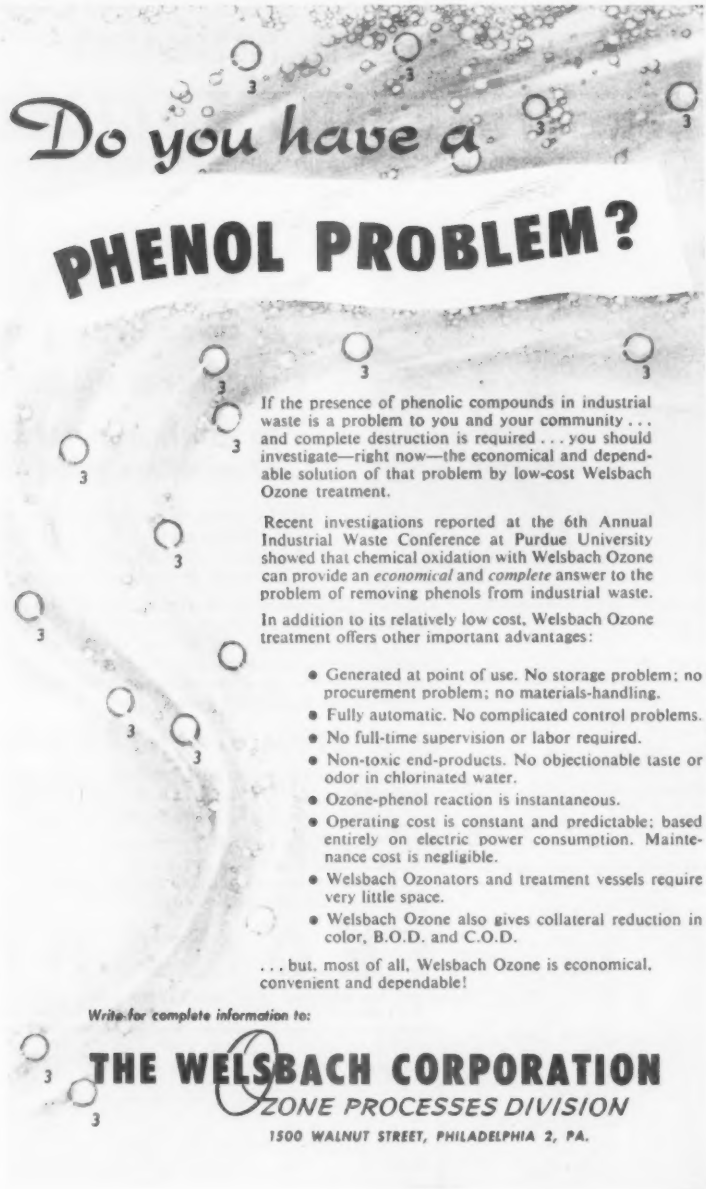
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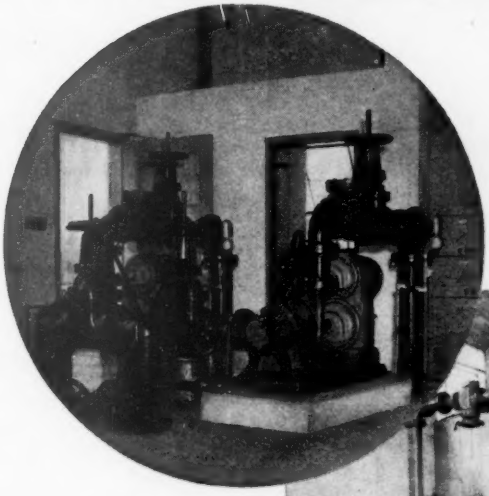
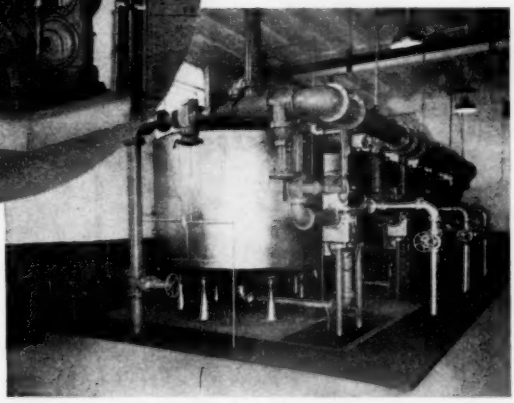
for these sparkling Florida plants



Glamortex – an alkyd resin enamel – adds a glossy mar-resistant finish to machinery, railings, piping and non-submerged metal surfaces in Orlando's Sewage Treatment Plant. Sturdy *Inertol Standard Thick* protects submerged metal surfaces.



Metal surfaces throughout the Jacksonville Beach Water Softening Plant retain a lasting high-gloss finish with *Glamortex* and *Ramuc Utility* Enamels. And their superior performance means long-range economy as well.

Jacksonville, Florida, engineers choose INERTOL coatings developed especially for water works and sewage plants

● When "specification" time rolled around, Consulting Engineers Smith and Gillespie selected Inertol Paints to keep these Florida installations protected and bright looking. Following Inertol recommendations, they discovered Inertol coatings that met their exact requirements for hardness, elasticity, weather-resistance, etc.

Each product in the broad Inertol line has been proved in thousands of installations in all parts of the country. Our Field Technicians will gladly discuss the superior performance and substantial economy of the Inertol line. Send today for our free "Painting Guide," prepared especially for Consulting Engineers, Design Engineers and Specification Writers. It indicates the most suitable type coating for every surface. Plant Superintendents and Contractors will also find it invaluable. You'll refer to it time and again!

INERTOL CO., INC.

482 Frelinghuysen Avenue
Newark 5, New Jersey

27 South Park, Department 2
San Francisco 7, California

Aero-Accelator and Biosorption Process

IN SEWAGE TREATMENT

For best results use the team that goes together *best*...
Infilco's BIOSORPTION PROCESS and the AERO-ACCELATOR.

The BIOSORPTION PROCESS has shown phenomenal results in the reduction of B.O.D. and suspended solids. So also are the results in efficiency, low maintenance and appreciable space-savings. The advantages of the AERO-ACCELATOR as a combined mixer-clarifier have been proved in many diversified installations. Together these two form a winning team.

Ask for bulletins describing Infilco's BIOSORPTION PROCESS and the AERO-ACCELATOR. See how the combination of these two can pay out handsomely.

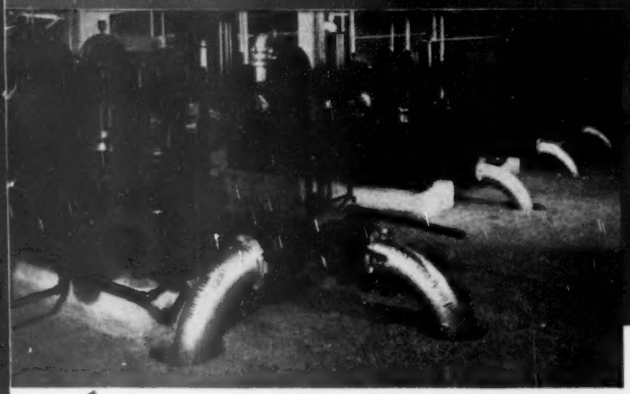
INFILCO since 1894

INFILCO INC. *Tucson, Arizona* | *Plants in Chicago & Joliet, Illinois*

FIELD ENGINEERING OFFICES IN 26 PRINCIPAL CITIES

World's Leading Manufacturers of Water Conditioning and Waste Treating Equipment

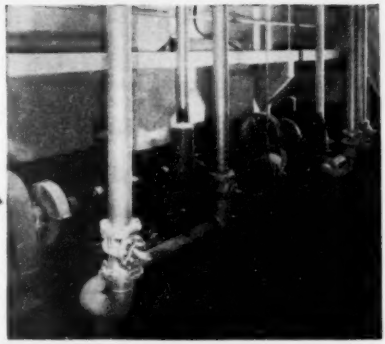
Straight-Through Flow, Unexposed Seats MAKE NORDSTROMS *Best* FOR SEWAGE PUMP LINES

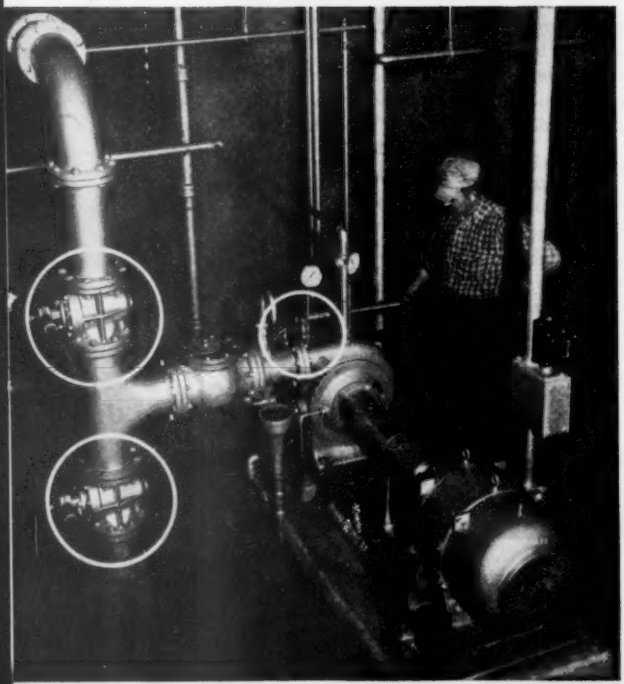


Nordstrom valves on displacement sludge pumps.

Easy-to-operate Nordstroms at head of main pump lines.

Emergency centrifugal sludge pumps with Nordstrom valve control.





In Nordstrom valves there are no pockets or recesses to collect foreign matter. When a Nordstrom valve is open the seating surfaces are out of the line of flow, protected from erosive or corrosive substances. And, open or closed, the internal lubrication system forms an uninterrupted ring of protective, plastic-type lubricant around the seat port for drop-tight closure, even after years of hard service.

These features combine to make Nordstrom valves best for the exceptionally difficult conditions in sewage treatment lines. Typical of these demanding services are pump lines.

For all types of sewage plant pump lines . . . in fact, for almost any sewage plant service, you'll be money ahead to specify Nordstroms from the start.

Typical Nordstrom Services In Sewage Treatment Plants

Lateral Air Lines	**Water**
Sludge Lines	**Metering Lines**
Grit Chamber Drain Valves	**Digester Lines**
Pump Suction and Discharge	**Filter Lines**
Sewage Gas	**Bucket Elevator Lines**

Write for Bulletin No. 1031 describing Rockwell-built Nordstrom valves, gas meters and water meters for sewage service.

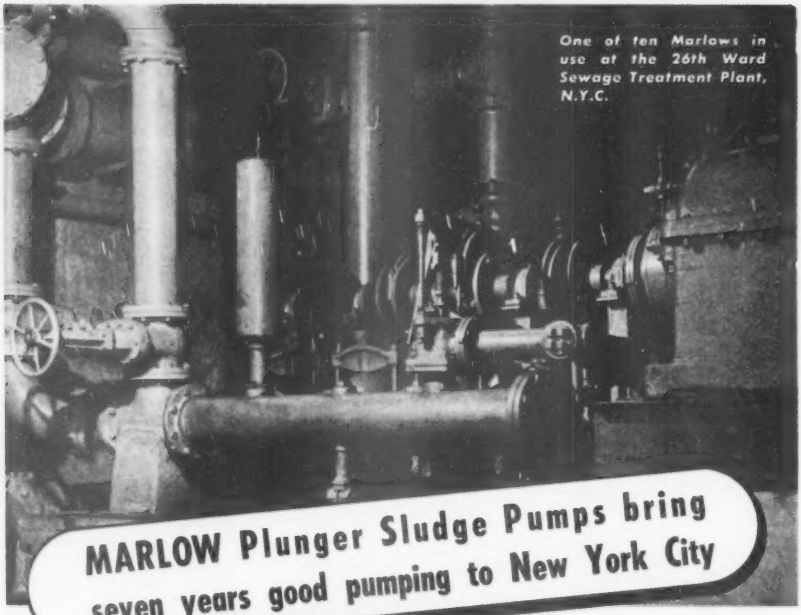
Rockwell Built Nordstrom Valves

Lubricant Sealed to Keep Upkeep Down

Rockwell Manufacturing Company

400 N. Lexington Ave., Pittsburgh 8, Pa.

Another ROCKWELL Product



One of ten Marlows in use at the 26th Ward Sewage Treatment Plant, N.Y.C.

MARLOW Plunger Sludge Pumps bring seven years good pumping to New York City

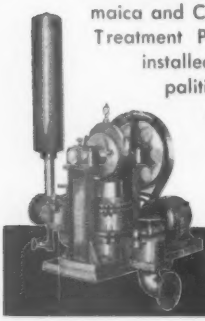
. . . and MORE

Most of the ten Marlows installed in this big plant have been on the job since 1943. Four are used for primary sludge, one pumps grease from the primary system to digester, three handle excess secondary sludge and two pump digested sludge from digesters.

Other Marlow New York installations include the Bowery Bay, Jamaica and Coney Island Sewage Treatment Plants. Marlows are installed in over 400 municipalities across the nation. And still the list grows. At present, big Marlow installations are being made by the city of Baltimore, at Nut Island Sewage Disposal Plant in Boston and at the North Point Sewage Disposal Plant in San Francisco.

Marlows are preferred because they are more efficient, reliable and durable. Marlow Plunger Sludge Pumps are the result of years of advanced pump engineering. They are available with single, double, triple and quadruple plungers. 360 to 30,000 GPH standard displacement.

Write for details. Inquire also about the famous Marlow Self-Priming Centrifugal pumps — portable and stationary models — and Marlow Portable Diaphragm pumps.

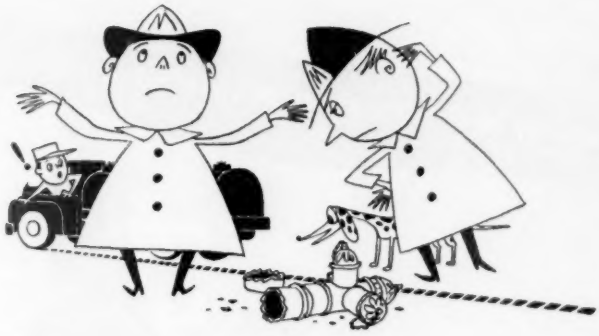


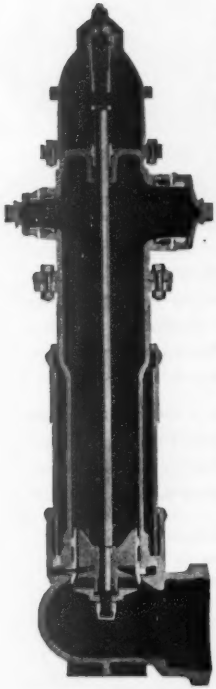
MARLOW PUMPS

416 GREENWOOD AVENUE
RIDGEWOOD, NEW JERSEY

Manufacturers of the World's Finest Sludge Pumps

Broken hydrant cannot leak!





The main valve opens against water pressure and closes with it. This is foolproof protection against flooding when hydrants are broken in traffic accidents.

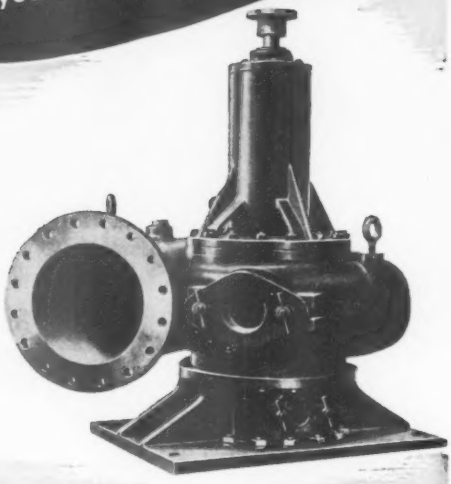
MATHEWS
HYDRANTS

Made by R. D. Wood Company Public Ledger Building, Independence Square, Philadelphia 5, Pa. Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves.

Mathews Modernized Hydrants . . . Tops in Convenience and Dependability Compression-type valve prevents flooding • Head turns 360° • Replaceable head • Nozzle sections easily changed • Nozzle sections raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • Operating thread only part to be lubricated • All working parts contained in barrel • A modern barrel makes an old Mathews good as new • Available with mechanical joint pipe connections

when it's pumps, think of Economy

backed by over thirty years of specialized experience



The Mixed Flow Volute Pump illustrated is just one of the many types in the extensive line manufactured by Economy Pumps, Inc. Available in capacities to 80,000 G.P.M., it is designed for service where large volumes of liquids are to be handled.

Maintenance expense is held to a minimum. Case records show Economy Pumps operating for fifteen to twenty years without replacement of major parts. However, should repairs be necessary, all parts are renewable.

Catalog No. F-1049 gives complete design and construction details. Address Dept. AC-3 for your copy.

Centrifugal, Axial and Mixed Flow Pumps for all applications

Economy Pumps Inc.

Sedgley Ave. at 19th and Lehigh, Philadelphia 32, Pa.

CLAY PIPE—*ESSENTIAL* ★ *ECONOMICAL* ★ *EVERLASTING*

Tucson, Arizona, enlarges its municipal sewerage facilities in a $2 million program caused by defense expansion. Clay Pipe is specified not only for the sewerage project, but for the new electronics plant, the adjacent airport, the additional housing, and the Air Force base which made it necessary.

84 MILES OF CLAY PIPE INSTALLED IN TUCSON MUNICIPAL SEWERAGE PROJECT

Over 440,000 feet of Vitrified Clay Pipe, in sizes ranging from eight to twenty-one inches, are being installed to meet the problems posed by defense plant, airfield, and housing construction in Tucson. The defense projects, totalling over $20 million, have caused an influx of thousands of people. Vitrified Clay Pipe sewerage systems will give them the *permanent*, corrosion-proof sanitary facilities that prevent sickness and epidemics.

Clay Pipe is the *only* chemically inert pipe . . . the only pipe that's unaffected by rust, rot, decay, sewage gases, or acid action. It's the one pipe that has *proved* its resistance to chemical action through decades of actual performance in the ground. Don't take chances with non-clay materials. Specify Vitrified Clay Pipe . . . *it never wears out!*

NATIONAL CLAY PIPE MANUFACTURERS, INC.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.

WHEREVER RELIABLE, PERFORMANCE-PROVED PIPE IS NEEDED, SPECIFICATIONS CALL FOR VITRIFIED CLAY

Rantoul, Ill. (Chanute Field)	158,000 ft.
Orlando, Fla. (Air Force Base)	74,000 ft.
Morrisville, Pa. (New Steel Defense Plant)	300,000 ft.
Rapid City, S. D. (Air Base)	54,000 ft.
Bakersfield, Calif. (Air Base)	196,000 ft.
Panama City, Fla. (Municipal Expansion)	450,000 ft.
Limestone, Me. (Air Force Base)	65,000 ft.
Tucson, Ariz. (Air Base)	440,000 ft.

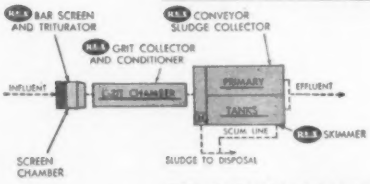
Vitrified CLAY PIPE NEVER WEARS OUT!

C-352-1

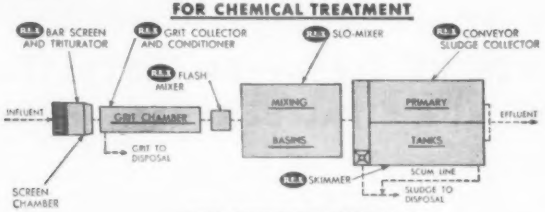
for best

PLAN YOUR PLANT

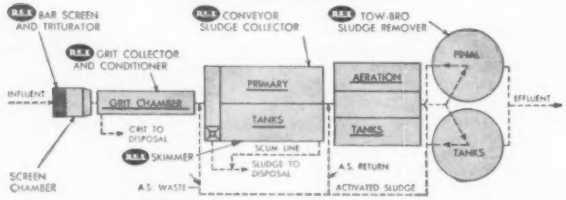
FOR PRIMARY TREATMENT



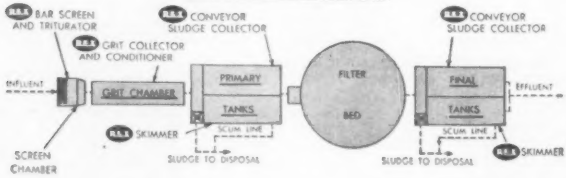
FOR CHEMICAL TREATMENT



FOR ACTIVATED SLUDGE



FOR TRICKLING-FILTER



RESULTS

ALONG THE REX LINE

Here's Why!

1. Modern treatment plants, regardless of size or type of process, require a multiplicity of arrangements and units.

2. The complete Rex line provides a broad selection of equipment that will best fit your requirements.

3. Selection of the *right* equipment is extremely important. The finest equipment in the world will not perform efficiently and economically if it is improperly applied.

4. Rex Sanitation Engineers are well qualified by years of training and experience to help you select the equipment which will best fit into your plans. Call them in when your job is still in the planning stage. You'll find it pays off in greater plant efficiency, improved performance, lower operating and maintenance costs. Chain Belt Co., 4606 W. Greenfield Ave., Milwaukee 1, Wis.

Chain Belt COMPANY
OF MILWAUKEE

CHAIN BELT REX COMPANY ®

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago
Cincinnati • Cleveland • Dallas • Denver • Detroit • El Paso
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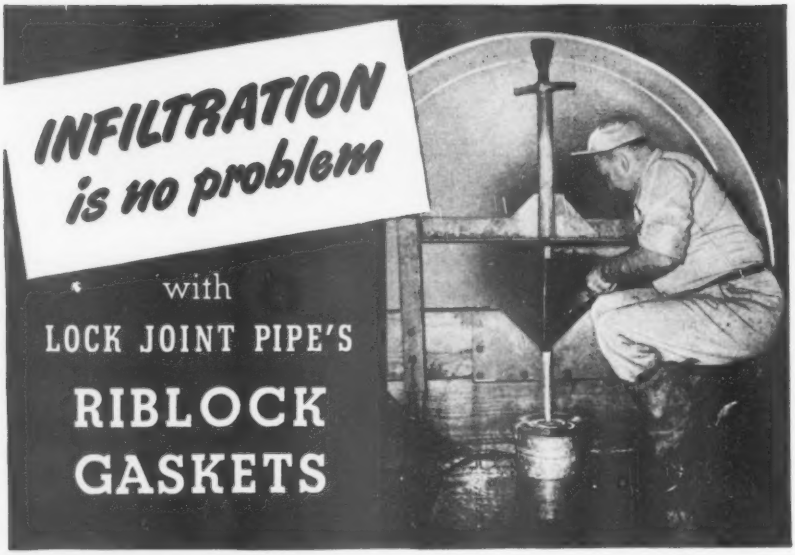

Actual field tests made on pipe laid under severe ground water conditions prove that the problem of infiltration can be overcome by using Lock Joint Reinforced Concrete Sewer Pipe equipped with Riblock Gaskets.

Bogert-Childs Associates, consulting engineers for the enormous Overpeck Sewer Project, conducted a detailed weir test on approximately 7,000 feet of 60" Lock Joint Reinforced Concrete Sewer Pipe with Riblock joints which were installed across the North Jersey swamps and marshlands. This test, which showed only 15 per cent of the volume of infiltration permitted in the specifications, pointed conclusively to the value of Lock Joint sewer pipe and Riblock gaskets for installations of this difficult nature.

For nearly 50 years Lock Joint Pipe Company has been furnishing the most durable and dependable sewer, storm drain, and culvert pipe obtainable. Now, by including Riblock Gaskets in the specifications, you can also assure joints with permanently reliable protection against ground water infiltration.

• • • • •

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, New Jersey

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. Denver, Col. • Kansas City, Mo. • Valley Park, Mo. Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. M. Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis.

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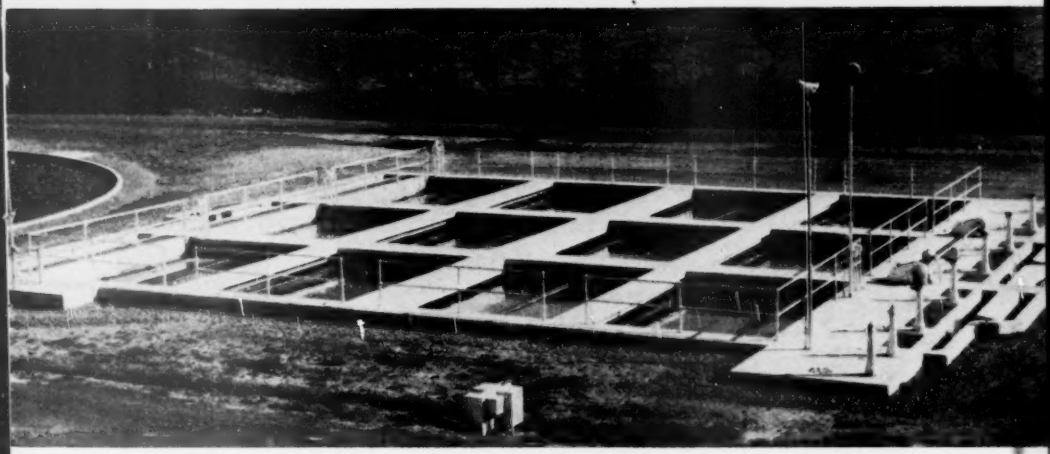
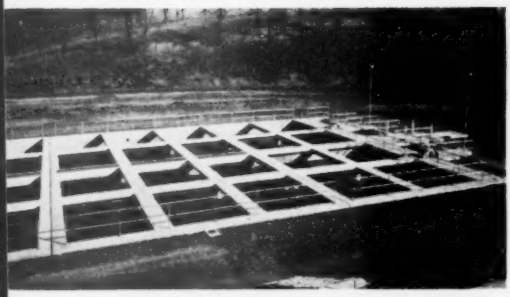
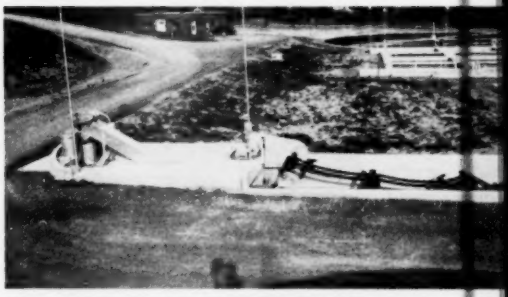


ROTOLINE SKIMMERS and Straightline Sludge Collectors in three 20 x 70 ft. primary settling tanks reduce suspended solids 59%, under actual operating conditions, in 1.76 hour detention time. Settling rate is 1220 gpd per sq. ft. tank area.

How to treat sewage for ¼¢ per day per capita



STRAIGHTLINE SLUDGE COLLECTORS — two longitudinal and one cross type — convey sludge to sumps in four 33 x 115 ft. final settling tanks. Peak-cap bearings, pivoted flights and "Straightline" action provide a positive, efficient combination.



STRAIGHTLINE GRIT COLLECTOR AND WASHER for 30 ft. grit chamber effectively collects, washes and removes settled grit — separates it from putrescible organic matter. Long-wearing Promal collector chain and rugged screw conveyor give low-cost long life.

LINK-BELT equipment plays prominent role at efficient Winchester, Va. sewage treatment plant

A PIONEER in Virginia's intensified pollution-abatement campaign, the city of Winchester recently placed in operation a 2.4 mgd Bio-filtration Plant. Designed by Alexander Potter Associates, consulting engineers, the plant is giving excellent sewage treatment at an operating cost of only ¼ cent per day per capita.

Major equipment used in this installation includes Link-Belt Straightline Sludge Collectors for all primary and final settling tanks, Rotoline Grease Skimmers and Straightline Grit Collector and Screw Conveyor-Washer.

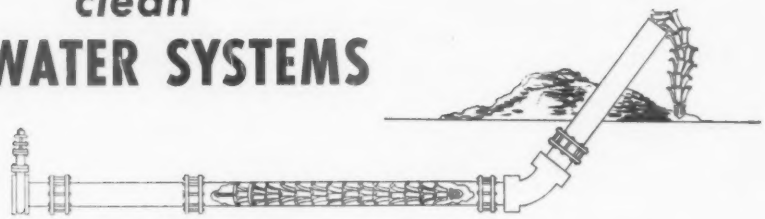
The complete L-B line is designed and built to highest standards and backed by more than 30 years' experience in this field. Link-Belt sanitary engineers will work with your engineers, chemists and consultants — help you get the best in modern liquid treatment.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

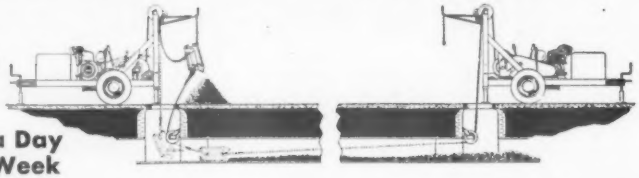
LINK-BELT COMPANY: Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa). Offices in principal cities. 12.938

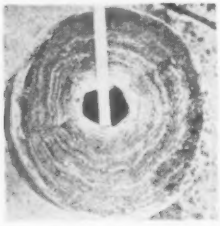
ACE Pipe Cleaning Contractors *clean* WATER SYSTEMS



and SEWER SYSTEMS

Anywhere
Any Time
Any Size
24 Hours a Day
7 Days a Week





Neglected city and industrial water pipes fill with debris like this—cut down service, increase fire rates. Let ACE clean them for you!

✻ Ask to see our new 21-minute newsreel movie of the great Kansas City Flood of July, 1951. No cost or obligation.

Fast, modern water pipe and sewer cleaning service —that's what ACE Pipe Cleaning Contractors, Inc., offers your city or industry *today*, wherever you are in the United States or Canada!

Preserve your system "for the duration," while pipe and steel are in short supply, with this thorough, economical service.

ACE brings the most modern equipment known to the job, plus trained, skilled crews to get the job done right, quickly and at *lowest possible* cost. ACE has representatives in several principal cities, ready to serve you. Write for further information. Let us send a man, at no expense or obligation to you. Get in touch with us today!

Cleaning jobs done thus far in 1951: Corps of Engineers, U. S. Army; City of Kansas City, Missouri; City of Kansas City, Kansas; Swift & Company; Armour & Company; Cudahy Packing Company; General Motors Corporation; Olathe, Kansas; Belton, Missouri; Milburn Country Club; Council Grove, Kansas; Procter & Gamble Mfg. Company.

ACE Pipe Cleaning Contractors, Inc.
2003 Indiana — CHestnut 2891 — Kansas City 1, Mo.

. . . it's the new RING-TITE JOINT used with Transite Sewer Pipe

NO NEED TO LET ordinary time-consuming methods of making joints slow down your sewer line jobs—not when you install Transite Sewer Pipe with its new Ring-Tite Coupling.

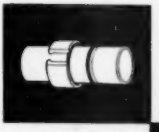
Just a simple assembly operation with a mechanical coupling puller and this new "packaged" joint is ready for business! No jointing compounds to bother with . . . no heating equipment . . . no special skill is required. And you can check each joint for proper assembly as soon as it is made—*before backfilling.*

Moreover, this easily assembled Ring-Tite Coupling makes a tight joint that *stays* tight in service. This, plus the fact that Transite's long 13-foot lengths mean *fewer* joints in the line, cuts infiltration to a minimum.

Another advantage of this asbestos-cement pipe is its high flow capacity (Manning's n=.010.). This often permits flatter grades and shallower trenches—an important economy where pipe is laid at or below ground water line or where rock excavation is required.

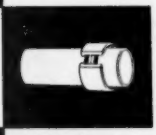
May we send you more complete data? Address Johns-Manville, Box 290, New York 16, New York. Ask for folder TR-103A.

HERE'S HOW IT WORKS:



◀ Start of assembly. Two rubber rings and Transite sleeve (cut away to show position of rings) are placed on one of the two pipe ends.

Final position. ▶ Sleeve centered over pipe ends, with the rubber rings tightly compressed between sleeve and pipe.



◀ Checking joint for proper assembly. This is done with a simple gauge immediately after the joint is made . . . *before backfilling.*

Transite is a registered Johns-Manville trade mark

Johns-Manville TRANSITE SEWER PIPE

to aid peak
defense production

Collect and Sell your Iron and Steel Scrap

Mr. Q-Check says *dig* for scrap metal —*search* every nook and corner of your pipe yard—*scrape* the bottom of the barrel! For iron and steel scrap is critically needed to aid peak defense production in steel mills and iron foundries.

The average pipe yard has some or all of the following sources of scrap metal, according to whether pipe is used for water, gas, sewerage or industrial service:

Obsolete fittings; cut pipe (short pieces of distribution or service pipe); damaged hydrants, valve boxes, manhole covers, etc. It all adds up to a vital contribution to defense production.

Collect your scrap now. Phone your nearest scrap dealer. He wants what you have *but quick*, and pays good cash prices.

CAST IRON PIPE RESEARCH ASSOCIATION . . . CHICAGO

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 24 | MARCH, 1952 | Number 3

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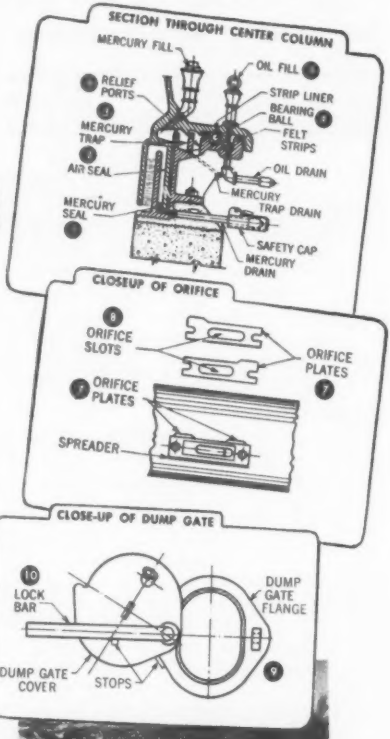

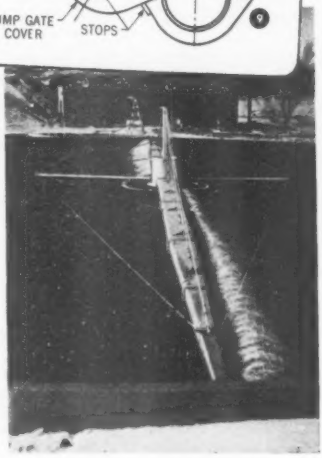

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Sewage Works

COLLOIDS IN SEWAGE *

I. Separation of Sewage Colloids with the Aid of the Electron Microscope

By Willem Rudolfs and J. L. Balmat

Rutgers University, New Brunswick, N. J.

Of the solid constituents present in domestic sewage, the colloidal fraction has been found to be one of the more difficult to treat. As a result, a long-term research project has been initiated to study the chemical and physical nature of sewage colloids. A better understanding of the nature of these colloids may well provide the basis for a more calculated approach to their treatment. It would be expected that information obtained would also have applications in water and industrial waste treatment.

An appreciable amount of work has been done in the past by many investigators interested in this problem. Critical reviews of the subject written by Mills (1) and by Rudolfs and Gehm (2) cover the period from 1900 to 1939. A survey of the literature since 1939 has revealed no new information on the subject. In the studies in which it was the purpose to determine the amount of the colloidal matter in sewage, "each writer tacitly assumed an arbitrary distinction between the suspended and the colloidal matter, but none attempted a critical study of the method of differentiation adopted in his investigation or justified the definition of colloidal matter . . ." (1).

This first paper of a series on sewage colloids is an endeavor to establish the nature of the colloidal fraction in relationship to a definite particle size range. The investigation is limited to a study of the removal of the colloidal fraction of sewage constituents as a step preliminary to chemical analysis, and to a study of the physical appearance of these colloids.

Colloids have been described on the basis of several different properties. If only one characteristic were to be selected to distinguish colloidal particles from all others, it would be size. The lower limit of those particles in the colloidal state is generally considered to border on the state of true solution, thereby fixing the lower limit of colloidal matter size at about 1 millimicron ($m\mu$.) The upper limit of the colloidal state with respect to particle size has not been definitely established. Various authorities have set the upper limit at: 0.1 μ., 0.5 μ., 1.0 μ., and higher (3). It has been arbitrarily established in the current study of sewage colloids that particles within approximate limits of 1 μ. and 1 $m\mu$. will be considered as true colloids. With the aid of the electron microscope, particles within the colloidal range can be measured with ease and accuracy. It is recognized, however, that particulate matter of a particle size greater that 1 μ. frequently shows very definite colloidal characteristics. Future investigation into the chemical nature

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

of sewage colloids will, of necessity, include these larger particles.

The smallness in particle size results in a tremendous surface area per unit weight of the colloidal substance, and it is the prevalent belief that the properties of colloids are more nearly dependent upon their surface area than upon their mass or inherent chemistry.

Two different kinds of colloids are found in sewage: (a) suspensoids, or minute solid particles, such as cellulosic material; and (b) emulsoids, or minute liquid droplets, such as oils. These colloids remain in suspension because of such properties as their minute size, state of hydration, and their surface charge.

In sewage treatment none of the colloidal matter is removed in the sedimentation tank. Chemical coagulation removes some of the sewage colloids. The colloidal fraction exerts one-third of the total chemical demand but it represents gravimetrically only one-sixth of the total solids present. Of

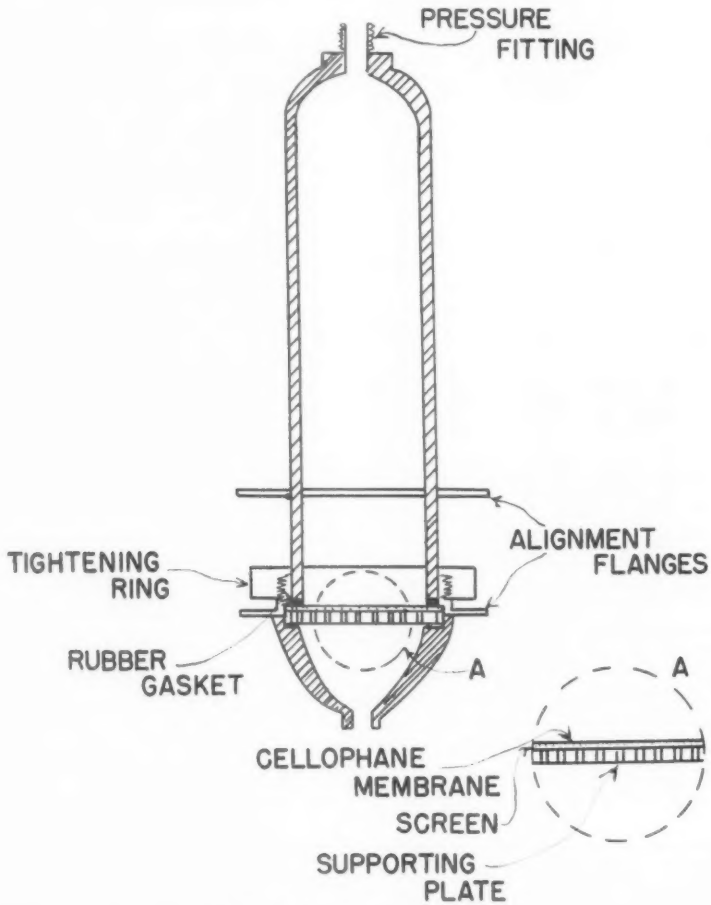

FIGURE 1.—Ultrafiltration unit.

TABLE I.—Effect of Treatment on the Solid Constituents of Sewage

Sample	Max. Particle Size (μ)	Turbidity (p.p.m.)
1. Raw sewage	—	490
2. Settled, 1 hr.	100	400
3. Settled, 4 hr.	80	340
4. Filtered through No. 602 Filter Paper	1	120
5. Filtered through Gooch crucible	—	82
6. Filtered through Seitz filter	0.58	28
7. Filtered through Cellophane ultrafilter membrane	0.08	8
8. Centrifuged batchwise, 2,000 r.p.m., 4 hr.	0.84	100
9. Centrifuged continuously:		
a) 21,000 r.p.m.; flow = 10 c.c./min.	0.53	55
b) 21,000 r.p.m.; flow = 100 c.c./min.	0.53	55
10. Centrifuged continuously:		
a) 2,000 r.p.m.; flow = 100 c.c./min.	5	170
b) 6,000 r.p.m.; flow = 100 c.c./min.	2.5	154
c) 12,000 r.p.m.; flow = 100 c.c./min.	1.5	135
d) 14,000 r.p.m.; flow = 100 c.c./min.	1	123

all the sewage treatment processes, biological purification is the most efficient in the removal of colloids. The fact that the activated sludge process reduces the suspended solids by about 90 per cent gives little indication, however, of the extent to which the colloidal matter itself is reduced. It is evident that a fundamental study of the chemical and physical nature of the colloids in sewage may measurably aid in furthering the progress of sewage treatment.

Methods of Removing Colloids

Two methods generally used in the removal of insoluble materials have been studied: filtration and centrifugation. Filtration of domestic sewage through filter paper, Gooch, and Seitz filters was tried as a possible means of removing the supra-colloidal fraction, and the low-speed centrifugation of the sewage at 2,000 r.p.m. was conducted to establish the efficiency of this method commonly used in laboratory practice. The term "supra-colloidal fraction" refers to that particulate matter having a size greater than 1 μ. Ultrafiltration and high-speed centrifugation were used as possible means of removing sewage colloids quantitatively.

In all the experiments domestic sewage from the Highland Park sewage treatment plant screened through a No. 30 mesh sieve, was used.

Filtration

1. Filter paper, Schleicher and Schüll, No. 602. A 100-c.c. sample of sewage was filtered through the filter paper under partial vacuum derived from a laboratory water aspirator.

2. Gooch filter. An asbestos fiber mat 3 to 5 mm. thick was prepared in a Gooch crucible, according to "Standard Methods" (4). A sample of fresh domestic sewage was filtered through the Gooch crucible. The first 20-c.c. portion of the filtrate was discarded, then a sample of the filtrate was taken for a turbidity measurement and for an electron microscopic study.

3. Seitz filter. An S1 Seitz filter sheet, in a Seitz filter unit, was thoroughly rinsed with distilled water, the filter pad drained of the excess water, and the sewage sample filtered. The first 20-c.c. portion of the filtrate was discarded, then a sample of the filtrate was taken for a turbidity measurement and for electron microscopic study.

4. Ultrafilter membrane. Colloids previously have been removed quanti-

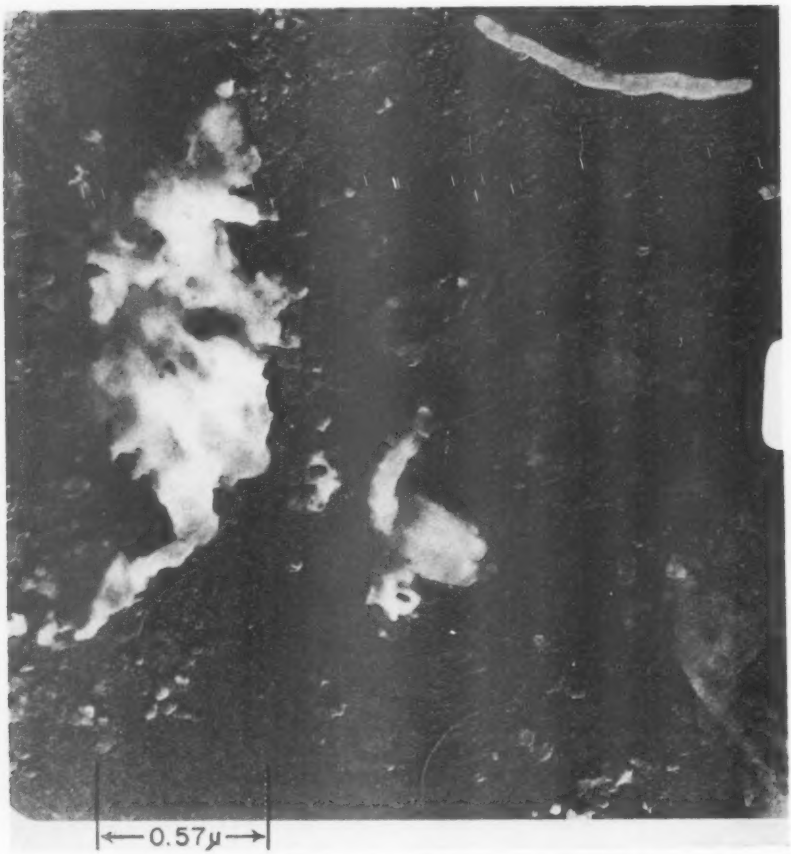

FIGURE 2.—Electron micrograph of domestic sewage supernatant from a 1-hr. settling period.

tatively by means of ultrafilter membranes (5). A commercial grade of Du Pont Cellophane (600 PT) having a thickness of 0.0016 in. was used in the studies. To prepare the sheet Cellophane so as to create a swollen structure suitable for ultrafiltration, the following steps were taken (6): The Cellophane was soaked in 65 per cent zinc chloride solution for 15 min. Care was taken to prevent folding of the membrane throughout the entire procedure. The zinc chloride solution was then drained off and the membrane rinsed several times in dilute hydrochloric acid over a 30-min. period. The hydrochloric acid was removed by rinsing the Cellophane membrane in distilled water for 30 min. After the excess water was drained off the membrane was ready for use.

The prepared Cellophane membrane was then placed in the pressure filter unit (Figure 1) and the raw sewage filtered under a pressure of 50 lb. per square inch. The first 50-c.c. portion of the filtrate was discarded, then a sample was taken for a turbidity meas-

urement and for electron microscopic study.

Centrifugation

1. Low speed. A 250-c.c. sample of raw sewage was centrifuged batchwise at 2,000 r.p.m. (a relative centrifugal force of 894 *G*) for 4 hr. in an International centrifuge, Size 1, Type SB. The sample for turbidity and electron microscopic study was taken 1 in. below the surface of the liquid sample by means of a pipette.

The continuous, low-speed centrifugation of the raw sewage was conducted with a motor-driven, laboratory model Sharples super centrifuge. Domestic sewage was centrifuged at 2,000, 6,000, 12,000, and 14,000 r.p.m. while flowing through at a rate of 100 c.c. per minute.

2. High speed. The high-speed centrifugation study was carried out with the Sharples super centrifuge operating at 21,000 r.p.m. At this speed the centrifuge developed a relative centrifugal force of 10,935 *G*. The sewage samples underwent centrifugation while flowing at rates of 100 c.c. and 10 c.c. per minute. The rate of flow was measured by means of a laboratory rotometer.

Results

Removal of Insoluble Matter

The extent to which the colloids and other insoluble matter present in sewage were removed by the various processes used is shown in Table I. An indication of the relative degree of removal of the particulate matter in the treated sample is reflected by the turbidity measurements and the maximum particle size values. To ascertain the effect on particle size reduction by sedimentation alone, measurements were also made on sewage which had been settled for 1 hr. and 4 hr.

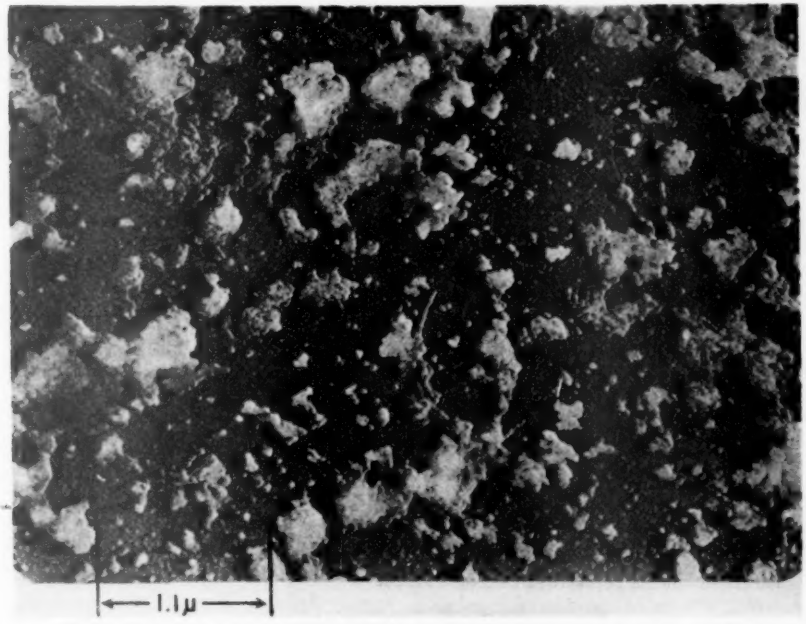

FIGURE 3.—Electron micrograph of domestic sewage supernatant from a 4-hr. centrifugation at 2,000 r.p.m.

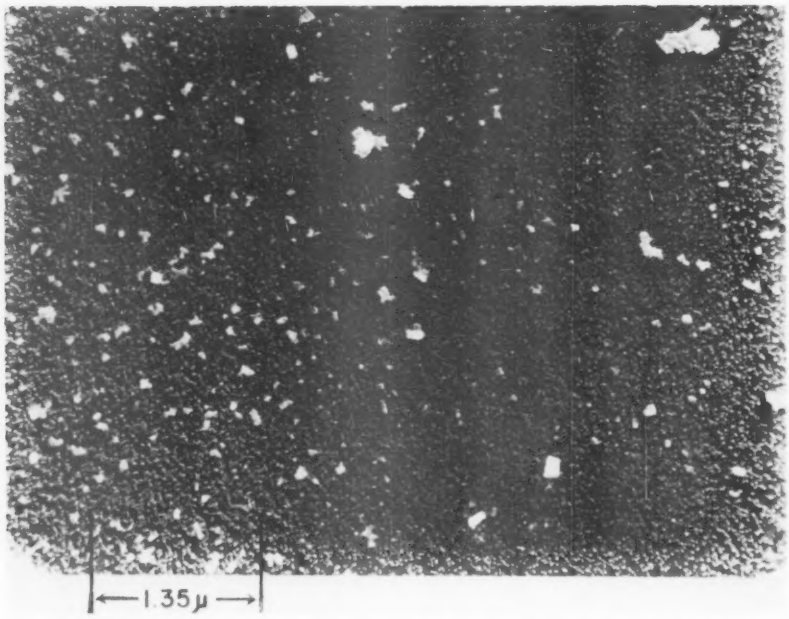

FIGURE 4.—Electron micrograph of settled domestic sewage filtered through a Seitz filter.

The results given as 1 to 10 in Table I represent different aliquots of a sewage sample, each aliquot having undergone a single type of treatment. All of the measurements on these samples were made within a single day. Several sets of results were obtained, but for the purpose for which the results were taken, one representative set was considered to be of more value than an average of several sets.

The maximum particle size was not recorded for the Gooch filtered sewage, for it was not possible to tell readily whether the larger particles were originally present in the sample or came from the asbestos mat.

Physical Appearance of Sewage Colloids

Electron micrographs were made of domestic sewage samples having undergone all the treatments indicated by Table I. Three photographs (Figures 2, 3, and 4) were selected which were most representative of the colloidal particles of various sizes. No single photograph gave the over-all picture, because of the heterogeneity of the sample and the minute area viewable at any one time with the electron microscope. For the same reason, no estimation of the particle size distribution was possible. A comparison of particle sizes between the three photographs is possible if the differences in the degree of magnification are noted.

Discussion

Separation of the Colloidal Matter

It has been stated that in sewage the insoluble matter exhibiting colloidal characteristics probably exceeds the upper limit of the colloid range as previously defined. For the present, however, attention is focused on that fraction of the insoluble matter consisting

of particles within the approximate limits of 1 μ. and 1 mμ.

In the separation of the colloids from the other constituents of sewage, it is first necessary to remove the supra-colloidal fraction. This may be accomplished by either centrifugation or filtration. Data in Table I show that continuous centrifugation of sewage at 14,000 r.p.m. removed the particulate matter of a size greater than 1 μ., the upper limit of the colloidal range. The batchwise centrifugation at 2,000 r.p.m. for 4 hr. appears to have resulted in a larger maximum particle size than was expected from the turbidity measurement, probably because of the resuspension of some of the less dense insoluble material during slowing down and stopping of the centrifuge.

The use of filter paper produced results similar to the 14,000 r.p.m. centrifugation. From a theoretical viewpoint it would seem that removal of the supra-colloidal fraction in sewage, while retaining the colloidal fraction in suspension, would be more satisfactorily accomplished by filtration than by either continuous or batchwise centrifugation. The filter paper acts primarily as a mechanical screen, withholding particles larger than the pore size of the paper and permitting those of a smaller size to pass through, regardless of their density. In dilute aqueous systems the surface of the filter paper is negatively charged, as are the sewage colloids, when the pH of the sewage is greater than 6.5 (8), thus making the filter paper inert to the colloids passing through. Further, it would seem that the separation of the supra-colloidal and colloidal fractions by continuous centrifugation would not be so well defined on the basis of particle size. As the rate of sedimentation of particles is governed, in addition to other factors, by particle size and density, it would appear that the centrifugation of a heterogeneous mixture such as sewage would result in the removal of some of the colloids of a greater density than the supra-colloidal particles but of smaller particle size. The merits of filtration *vs.* centrifugation, however, cannot be based only on theoretical speculation. The filtration of the first 100 c.c. of domestic sewage through the filter paper produced a colloidal solution having a maximum particle size of 1 μ. Thereafter the rate of filtration decreased rapidly, accompanied by a decrease in the maximum particle size in the filtrate, indicating that the non-filterable solids on the surface of the filter paper were reducing its effective pore size. If the first 100 c.c. of filtrate passing through the filter paper (Table I, sample 4) is considered as containing only the colloidal fraction of the sewage insoluble solids, then maximum particle size and turbidity measurements indicate that centrifugation at 14,000 r.p.m. (Table I, sample 10d) produced comparable results. In this respect, continuous centrifugation will produce a large volume of effluent of constant physical nature, whereas filtration produces a filtrate of changing nature.

Filtration of sewage through a Gooch crucible is used to remove what "Standard Methods" (4) defines as "suspended solids." If the turbidity value of 120 p.p.m. (Table I, sample 4) is taken as an index of the total colloid content of sewage, the turbidity of 82 p.p.m. for Gooch filtered sewage indicates that the term "suspended solids" includes all of the supra-colloidal fraction and some of the colloidal fraction. The Seitz filter has been used on occasion to remove the more finely dispersed portions of the non-settleable solids (9). In Table I, it can be seen from both the maximum particle and turbidity measurements that this type of filtration, although more efficient in the removal of the insoluble matter than is Gooch filtration, permits the passage of a small amount of the colloidal matter. Filtration through the Gooch and Seitz filters,

because of their pore sizes and because they are subject to the same ills as paper filtration, cannot be used in the separation of the colloidal fraction.

After the removal of the supra-colloidal fraction of sewage solids by continuous centrifugation, the next step in the isolation and concentration of the colloidal fraction for chemical analysis is the separation of the colloidal and dissolved fractions. Continuous centrifugation at a speed of 21,000 r.p.m. removed only a part of the colloidal fraction (Table I, sample 9b). Hauser anl Lynn (10), in the separation and fractionation of colloidal systems, have shown that under normal conditions if the rate of flow through the Sharples super centrifuge is quartered, the particle size in the effluent will be halved. However, reducing the rate of flow from 100 c.c. to 10 c.c. per minute made no change in the maximum particle size or turbidity measurements of the centrifuged sewage effluent, indicating that a substantial amount of the colloidal matter in sewage has a density the same as or less than the density of water.

A considerable amount of work has been done on the quantitative removal of colloids by ultrafiltration. An extensive review of the subject has been published by Ferry (11) and the more recent studies are reported by McBain (3). Neu, as early as 1923, used an Ostwald ultrafilter for the separation of dissolved materials from those considered to be in the colloidal state. In the present study an ultrafilter membrane of commercial Cellophane produced by du Pont was used because of its suitability and availability. As a rule, Cellophane when properly treated and swollen with 64 per cent zinc chloride solution will permit all molecules to pass through freely while retaining all colloids. This membrane has the advantages of being very thin (0.0011 in. when swollen), chemically inert, and insensitive (12). The thinness of the Cellophane membrane minimizes the extent to which soluble substances present in sewage will be sorbed by the membrane. Pressure filtration, through an ultrafilter membrane of sewage from which the supra-colloidal fraction has been removed previously was very effective. The turbidity value of 8 (Table I, sample 7) may have been due to a slight amount of leakage around the rubber gasket of the pressure filtration unit (Figure 1). The removal of the sewage colloids by ultrafiltration has the distinct advantage of being a concentration, as well as a separation operation. In this respect it is far superior to electrodialysis, which necessitates the final evaporation of the water after the soluble substances have been removed in order to obtain the colloidal substances in a high enough concentration to make chemical analysis possible. Ultrafiltration is also superior to chemical coagulation as a means of removing the colloidal substances, because chemical coagulation is usually accompanied by the sorption of substances present in sewage in true solution, thereby giving a higher concentration of colloidal matter than really exists (1).

The turbidity values listed in Table I are a reflection of both the concentration and the particle size range or the average particle size of the insoluble matter present in the sewage samples. These turbidity values, without having absolute quantitative meaning, can be used with the maximum particle size measurements to follow the course of the removal processes. A true quantitative expression of the relative turbidity values is to be presented in a later paper.

Physical Appearance of the Sewage Colloids

The use of the electron microscope in connection with this study of sewage colloids not only permitted an accurate measurement of particle sizes, but also made it possible to study the

physical appearance of the colloidal matter. In viewing the photographs, one must keep in mind that the technique used in the preparation of the samples for electron microscopic study made it impossible to obtain information on the concentration or particle size distribution of the colloidal matter.

Of the many electron micrographs made of domestic sewage before and after the various separation processes, three of the most representative were chosen. These cover almost the entire range of colloidal matter, as previously defined, from a particle size of 1 μ. to 80 mμ. Figure 2 shows the physical appearance of the larger colloid particles, Figure 3 shows predominantly the particles that are in the middle of the colloidal range, and Figure 4 shows the particles at the lower limit. Study and comparison of the photographs result in two interesting observations.

First, there appears to be a greater heterogeneity among the particulate matter of larger size, as shown in Figure 2. As the size decreases, the particles seem to become more and more homogeneous in their physical appearance, although in Figure 4 the apparent similarity among the small colloidal particles may be due to the inability of the electron microscope and the human eye to detect the irregularities.

The second observation may be considered initially as improbable. From the dissimilarity of the larger colloidal particles seen in Figure 2, it is not difficult to imagine the particles as being of different chemical composition, whereas the particles in the middle of the colloidal range (Figure 3) are photographically of the same shade and of the same general appearance, which suggests a similarity of chemical composition. The same thing can be said of the small colloidal particles shown in Figure 4. No attempt will be made to rationalize this line of thought at present, but the photographs suggest the possibility that the colloidal matter in sewage may be divided into at least three groups upon the basis of chemical composition.

In the examination of all of the sewage samples, it was apparent that the colloidal fraction of the insoluble matter in sewage included an appreciable number of the microorganisms present. Elford (13) ascribes to the sewage microorganisms an average size of about 150 mμ. Although the weight of the microorganisms of colloidal size is probably small in comparison to the total colloidal matter, these negatively charged (8) living colloids constitute a very definite part of the subject under investigation.

Summary and Conclusions

Separation of the colloidal matter in sewage from that in coarse suspension and in true solution has been studied by filtration and centrifugation. The efficiency of the various methods was determined on the basis of two factors —particle size measurements made with the electron microscope and quantity measurements in terms of relative turbidimetric values. Simultaneously with the particle size measurements, the physical nature of the sewage colloids was studied and recorded photographically.

As the result of this study the following conclusions were reached:

1. The supra-colloidal aggregates of sewage can be quantitatively removed by controlled centrifugation, and the colloidal fraction can then be quantitatively removed and concentrated by ultrafiltration.

2. The "suspended solids" as determined by Gooch filtration include the supra-colloidal fraction, as well as a portion of the colloidal fraction.

3. The Seitz filter will not remove all of the insoluble matter present in sewage.

4. On the basis of physical homogeneity and particle size the sewage

colloids can be divided into three groups.

Acknowledgment

The appreciation of the authors is extended to Nettie Coy and John Oskay of the Squibb Research Institute and to Jacob Joffe and Norman Slovik of Rutgers University for their assistance in the experimental portion of this study.

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SEWER SYSTEM RECORD KEEPING *

By K. B. Stallings

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The subject of this paper is purposely confined to collection system records, as there are many more collection systems than treatment plants. Everyone may think that the subject needs little discussion, that a record of the sewer locations is an obvious need, and that filing the construction plans provides adequate records. Perhaps the very fact that such record is so obviously necessary, furnishes the reason for so little discussion and exchange of information on the subject. Evidently this overlooking of the obvious is of long standing, to judge from the following:

Who builds a sewer, and plots its course with care?
Who later goes and proudly says "Dig right here"?
Where men dig and dig—and the d—n thing isn't there!
Just a poor bewildered Sewer Engineer!

A pertinent question at this point might be: "How many sewer superintendents know where all of their sewers are located?" Those who know are greatly to be envied.

No doubt many cities have better sewer records than does Nashville. In fact, if the records are not far better than are those available for some of the older areas of Nashville, the responsible parties are really in a predicament. The remarks to follow are not intended to provide a panacea for record troubles. They are presented as the case history of one municipality's struggle to enlarge and preserve its knowledge of its sewer locations. Those with adequate records can sit back and laugh at the tale of woe: fellow unfortunates can sympathize, and perhaps learn a few things to avoid.

Contributing Factors

Engineers of past generations often displayed keen foresight in locating and sizing sewers to serve future demands. However, it is readily apparent that they were primarily construction men, far more concerned with immediate achievement than with leaving a record of that achievement for the benefit of posterity. The present generation is also concerned with the necessity of immediate achievement in providing adequate sewerage for communities. It is further faced with the necessity of recording the "where" for both present work and some of that done by its remote predecessors. From day to day it is finding the "where" of the old-timers in the hard way—by exploration, both intentional and otherwise.

Other factors contribute to the difficulties. Some are probably familiar to many municipalities and to quite a few of the larger industrial plants; some may be peculiar to Nashville. One is the extreme age of part of the sewers, together with the corresponding lack of plans. Another stems from the practice of some of the earlier officials in allowing subdivision developers to build so-called "private sewers" and connect them to the city system, without requiring submission of plans therefor. Still another was the item of having the Engineering Department and the Sewer Department as autonomous divisions of the municipal organization.

* Presented at 24th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; St. Paul, Minn.; Oct. 8–11, 1951.

The Sewer Department ostensibly was for the work of maintenance, with the Engineering Department handling new construction by contract forces. However, many short sections of sewer were built by the Sewer Department, usually without surveys, plans, or grade stakes. Usually the only knowledge of such sewers was a brief memo to the effect that "*X* feet of *Y* size sewer has been built in Blank Street by city forces, John Doe, Supt." Often the memo contained less information, if there was a memo at all. As usual under such a set-up, each department guarded its independence quite zealously. Tradition quotes one old-timer as saying, "Who needs engineers' plans and stakes to make water run downhill?" It is also rumored that some of the engineers were inclined to change grades and say nothing about it.

It is almost an impossibility to follow initial construction plans verbatim in underground construction, especially in areas where other utilities have already been placed. However, it seems sheer imbecility to believe that the recording of construction changes is nonessential.

Earliest Plans

The extreme age of some of the Nashville sewers has been mentioned. It is not known whether or not there were ever any plans for the city's earliest sewers. These were merely square masonry structures, following the meanderings of existing ditches in many cases. The earliest plans available are 80 to 100 years old and were drawn on rolls of a type of eggshell paper; the majority of them now resemble used eggshells. Little information is shown thereon other than alignment stationing and deflection angles. The alignment was seldom tied to street margins or to other points now identifiable. These sewers were built with a minimum of manholes, and the majority of those built have long since been covered over. Retracing these lines is a terrific task, except where exploration has located a couple of key points. Of course, notations such as "6 feet deep here," and sections of profile plotted to an assumed datum are not much help where older low-lying sections of town have been filled some 20 to 25 ft. A recent exploration for one of these sewers went through two pavements below the present street before the sewer was revealed—almost on the opposite side of the street from the point first excavated!

"Roll Era"

The next stage, called the "roll era," entered its heyday about 60 years ago. This stage entailed the use of cloth-backed cross-section paper rolls. This material was purchased in rolls of 10- or 20-yd. lengths, and seldom was a roll ever cut. The plan was drawn on the portion of the roll surface not occupied by the profiles of the existing ground and of the grade line. The grid scale was 50 ft. to the inch horizontally and 5 ft. to the inch vertically. Although the plan was plotted with extreme care to keep the centerline parallel to the horizontal grid lines, the rugged local terrain necessitates frequent breaks in alignment and profiles. Clairvoyance is not a necessity in following some of these plans, but it certainly is quite an aid.

Naturally, there were many short sections of sewer. The general practice was to plot several of these on a portion of a long roll, and then to take the roll to the field for use as a construction plan. In the meantime, other sewers in the same general locality as those on the first roll were being plotted on a second roll. The inefficient situation of having rolls in the field when needed in the office, and *vice-versa*, apparently was commonplace. It isn't unusual to find sewers within a 4- or 5-block area on as many as three rolls, and there is as much as 25 or more

years variance in the completion dates noted on some single rolls.

To the credit of these rolls, they carry notations that are invaluable. Most meticulously listed are such items of information as profile of rock encountered and removed; location and sizes of other utilities encountered; locations and sizes of wye-branches installed; name of the contractor and/or construction superintendent; date of completion; and number of the field book in which survey and construction notes were kept. These items are listed on present-day plans, with the exception of the field book number. Present-day field notes are on loose-leaf paper and are filed in manila envelopes numbered to correspond with the plans.

Modern Conversion

This last stage of the "roll era" lasted into the early 1930's, and abandonment was not at all abrupt. Over a 3-year period, the rolls and the presently used 24-in. by 36-in. plan and profile sheets were mingled. Information is not readily available as to the reason for such reluctance to competely abandon the unwieldy system. (One of the engineers says it was their sporting blood—that earlier engineers wanted to set up a roll whereon the desired information would not always be at the opposite end from where the unrolling began!) The actual start of the change-over apparently was due to a factor blessed by some and damned by others; namely, the demands of federal agencies for many copies of documentation. Some of the sewers during this period were built with ERA, CWA, PWA, WPA, or similar alphabetical financing, and the multiple copies required were completely beyond the realm of accomplishment for the cloth-backed paper.

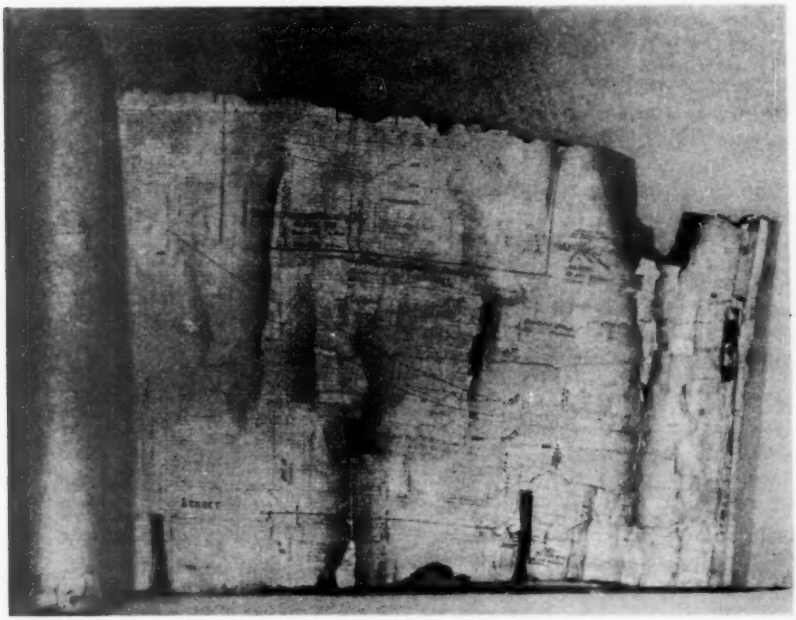

FIGURE 1.—One of the earlier rolls of plans and profiles.

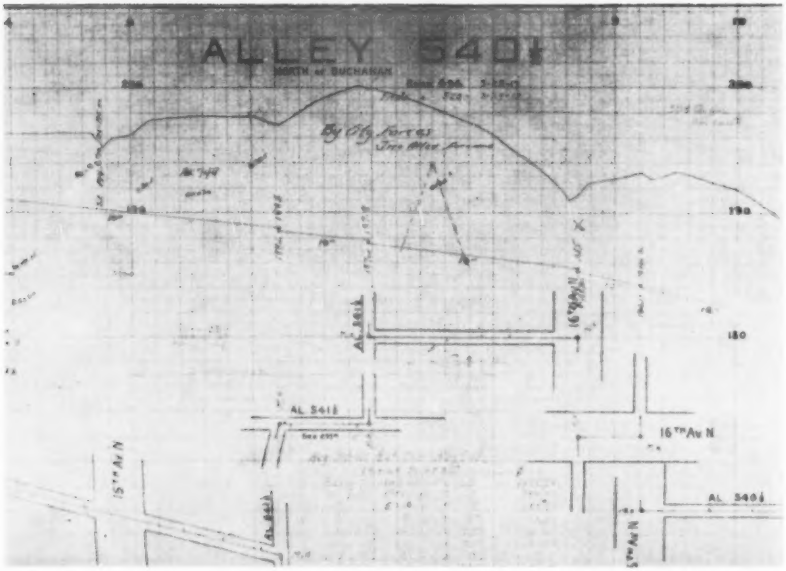

FIGURE 2.—A better roll of plans and profiles (about 1919); note alignment breaks and lack of stationing.

For the past 5 years slack time in the drafting room has been used to transcribe all types of "roll era" specimens. Such slack time has not been too plentiful, due to an accelerated construction program. Therefore, attention has had to be confined to those specimens classed by the staff as "basket cases"—rolls that must be unrolled over a basket if even a majority of the fragments are to be salvaged (see Figures 1 and 2). Of course, dozens of the olders ones disintegrated completely and were swept out years ago. Some of the missing plans have been replotted from the original field notes, when such could be located and deciphered.

The old field notebooks are stored where they are accessible, but the data in them are poorly indexed. Actually, the fastest reference to a book is from the notation of the book number on a roll; but when the roll is gone it's a long chase. Improving the indexing of these books is a winter project for the field parties.

Plans and Profiles

Construction plans are now drawn on 24-in. by 36-in. linen plan and profile sheets (see Figure 3). The plan, including all alignment details, reference ties, topography, and existing ground profile, is drawn in ink initially. Grade profiles and elevations are drawn in pencil, until completion of construction, whereupon the grades, and the notations previously mentioned, are inked on the sheet. It is recognized that current practice in most drafting rooms is to use pencil on paper for construction drawings. However, in Nashville these drawings are considered primarily as record drawings, with surprisingly frequent reference being made thereto, and linen has proven longer lived. It would be entirely possible to use pencil on paper for construction drawings, list the con-

struction changes, and then have reproduction tracings made on linen. Under present conditions, cost analysis is heavily in favor of the direct drawings on linen.

Storage of Drawings

Record drawings on any medium are completely valueless without simple and accurate methods of storing and indexing, requiring minimum time and effort for plans location at the moment of need. This is particularly true when the major use is by clerks servicing the public, rather than by engineering personnel. The majority of the public does not object too strenuously over reasonable delay, but if a line starts forming because of slowness in locating information, then each person in line immediately becomes an "irate taxpayer," well-known to be one of the highest explosives known to mankind.

For "roll era" storage, the inherited system is still used. No appreciable improvement can be seen to be made other than abandonment, which cannot come until such time as all rolls have been transcribed to standard sheets. One wall of a storage vault is lined with a rack of pigeonholes (Figure 4). Each holds 5 rolls and bears the number of the first roll filed therein. The rolls are numbered on the back at all four corners, so that no matter which end of the roll is exposed, the roll number is visible. The system is antiquated, a space waster, and a dust collector; but it must continue in use until the transcription work is complete.

The standard sheets are filed in numerical sequence within the fiber folder pockets of a metal planfile cabinet, which holds the folders vertically. Folders are nominally 42 in. by 30 in. in size. There are 60 folders in one cabinet, arranged in groups of four, and having a total capacity of 3,000 sheets. Numbering of the sheets is on a project basis, and the numbers are shown on the tabs of the file folders, along with the pocket and folder numbers (Figure 5). This storage system has proven far easier to handle than a conventional drawer file and is easier on sheets and on personnel patience.

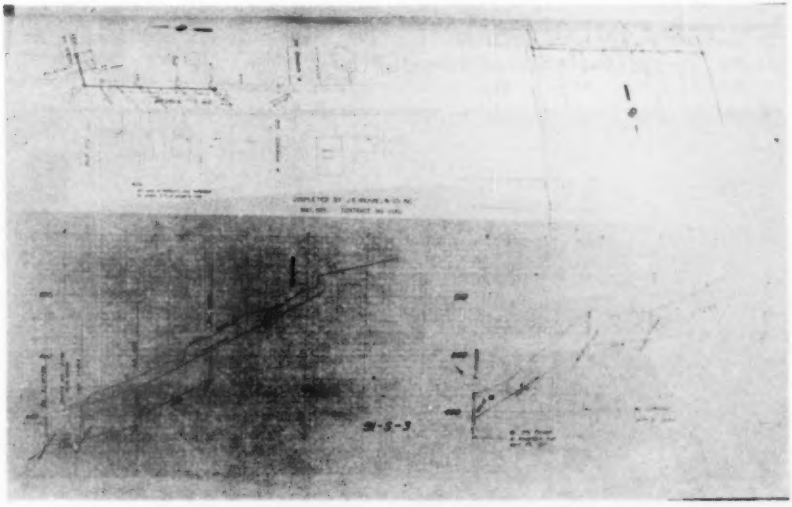

FIGURE 3.—Standard plan and profile sheet now in use.

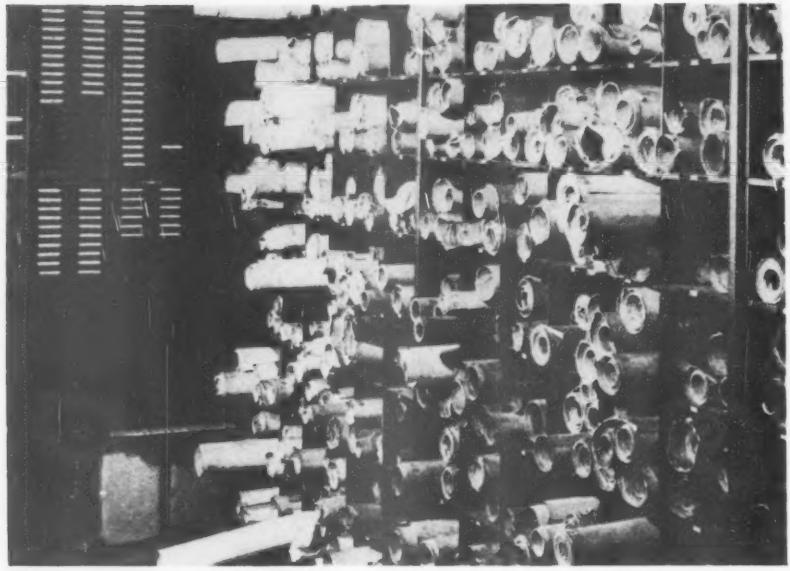

FIGURE 4.—Storage of old rolls of plans and profiles.

How are the desired plans extracted from storage? By two different methods. The first entails use of a couple of Kardex files. One section (Figure 6) lists all sewer plans in numerical sequence, with a brief description of the location, and with reference to planfile, pocket, and folder numbers. The other section has a card for each street and alley (Figure 7). On each of these cards are shown the plan numbers of the sewers located in that particular street or alley. Actually, however, these cards are by-passed in favor of the "sewer atlas."

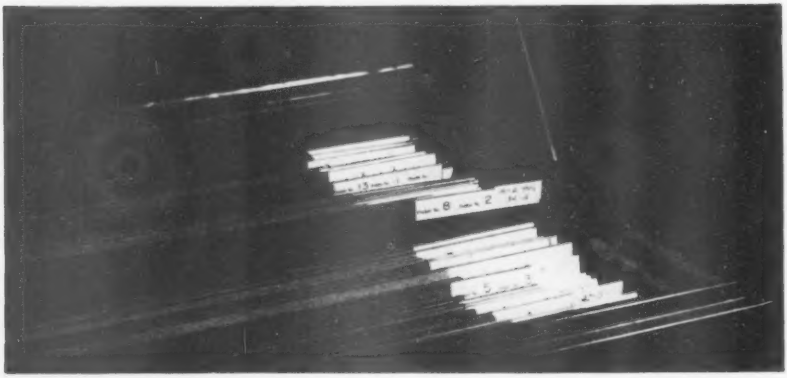

FIGURE 5.—Folder index of planfile cabinet used for standard 24-in. by 36-in. plan and profile sheets.

Somewhere in the past, someone set up a set of block maps of the city, drawn to a scale of 100 ft. to the inch. These maps on cloth-backed paper sheets, 18 in. by 30 in. in size, showed street and alley right-of-way lines and major subdivision lot lines as the basic pattern (Figure 8). Sewer lines were drawn thereon with colored inks. One color was used for stone sewers, another for brick sewers, and still others for vitrified clay and concrete pipe sewers. On the line denoting the sewer location was noted the size and the plan number of that particular sewer. There are approximately 170 of these sheets covering the city and some suburban territory. They, along with their small-scale key map, were kept at the public counter in three loose-leaf binders. Legend has it that the sheets now on hand were redrawn from the originals some 50 years ago. Although badly dog-eared, broken, dirty, and cumbersome, these are kept in drawers in the counter and used to some extent, particularly for some of the older sections where detailed plans are most conspicuous by their absence. The years have added such memos as "This sewer found on other side of the street," and "Haggerty says this sewer may go this way," with arrows drawn in two directions from a manhole. (Actually, exploration has proved Haggerty was wrong.)

In the 1930's, about the end of the "roll era," someone had the grandiose idea of using the block map system on a scale of 50 ft. to the inch. This map was to show streets and alleys, sanitary and storm sewers, street numbers, subdivisions, water lines, gas lines, telephone and telegraph lines and conduits, and street railway tracks. Seven years and $30,000 or $35,000 later, there emerged more than 700 linen sheets, 24 in. by 36 in. in size. On them was only the basic street and alley pattern, not too accurately done, and not all of the sewers. In addition to the more than 700 sheets of linen,

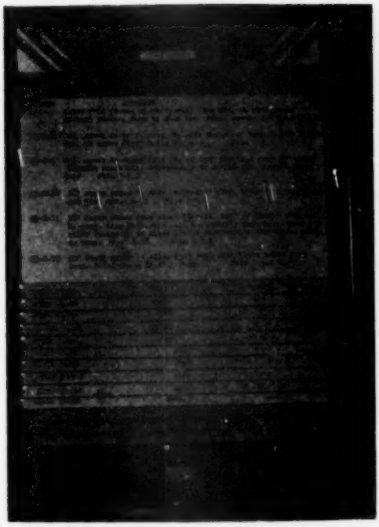

FIGURE 6.—Section of numerical card index to plans.

consider the cost of the time, the gallons of ink, three custom-built ledger-type post binders, more than 100 spoiled sheets, and two full sets of black and white prints. These constitute the reason for the shudders of the "top brass" when mention is made of budgeting funds to completely revamp the system.

The "sewer atlas" has now gone on a diet. The latest version is still based on the block map principle, but to a scale of 400 ft. to the inch (Figure 9). The Planning and Zoning Commission compiled these base maps, based on aerial and field surveys, covering the city and its immediate suburban areas on 16 sheets. Note the comparative number of sheets for the various scales —160 sheets for the limited coverage of the 100-ft. scale; more than 700 sheets for the same limited coverage by the nightmarish 50-ft. scale; and 16 sheets for far wider coverage by the 400-ft. scale. Two sets of reproduction tracings were made from the Commission's linens. The basic pattern was printed on the reverse side of the

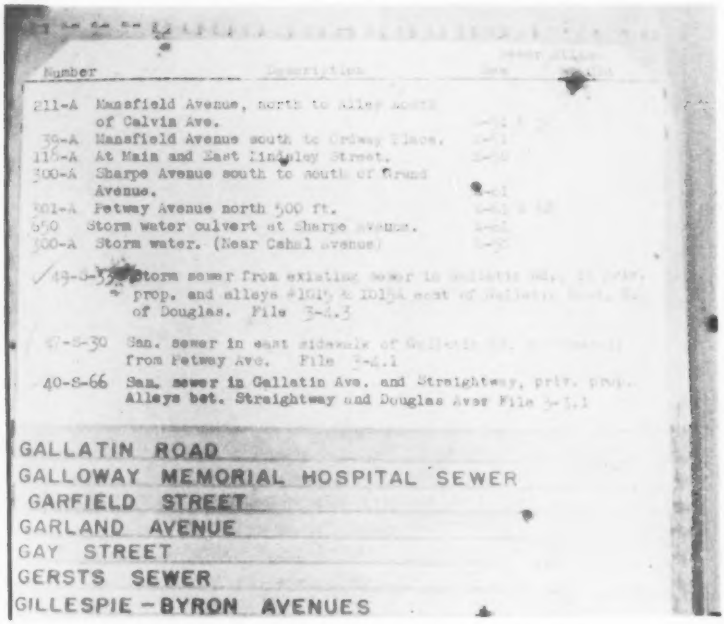
Number
211-A Mansfield Avenue, north to Alley
of Calvin Ave.
39-A Mansfield Avenue south to
115-A At Main and East Lindsley Street.
300-A Sharpe Avenue south to south of
Avenue.
301-A Fetway Avenue north 500 ft.
640 Storm water culvert at Sharpe
300-A Storm water. (Near Cahal avenue)
prop. and alleys
of Douglas. File
San. sewer in
from Fetway Ave. File
40-S-66 San. sewer in Gallatin Ave. and
Alleys bet. Straightway and Douglas
GALLATIN ROAD
GALLOWAY MEMORIAL HOSPITAL SEWER
GARFIELD STREET
GARLAND AVENUE
GAY STREET
GERSTS SEWER
GILLESPIE - BYRON AVENUES

FIGURE 7.—Specimen card of street index to plans.

sheets, so that changes and erasures can be made without destroying the pattern. One set of the reproductions, on vellum, has been used to begin the compilation of a basic drainage map, showing drainage areas, block by block drainage, and the storm sewers. The other set of reproductions, on linen, has been used to show all sanitary and combined sewers. The sizes and plan numbers are shown on these lines in the same manner as mentioned for the other schematics. A bound set of black-and-white prints from these "400's" is kept at the counter, thereby occasioning the by-pass of the card files previously mentioned.

As for the matter of keeping these schematic layouts up-to-date:—Proposed sections of sewer line are plotted, in pencil, on the black-and-white prints currently in use, when the plans are completed ready for construction. When construction has been completed, and the construction changes and final notations are being placed on the record drawings, the same draftsman shows the newly completed sewers on the schematic prints with colored pencil. At intervals of six months, all such notations are placed on the tracings, and a new set of prints made for counter use. This interval has been adopted because six months is the approximate life of a set of the prints in daily use at the counter. Reference from the schematics is fast and simple, because of the plan numbers noted directly on the lines. When inquiry is made of territory not already sewered, it is easy to tell at a glance whether plans are ready, or what trunks are available for extension into such area. Primary use, however, is by the clerks for fast reference to the plans.

There are better reference systems in existence. The Nashville one is rudimentary, but functions fairly well. Probably the ideal situation, from the standpoint of accessible public informa-

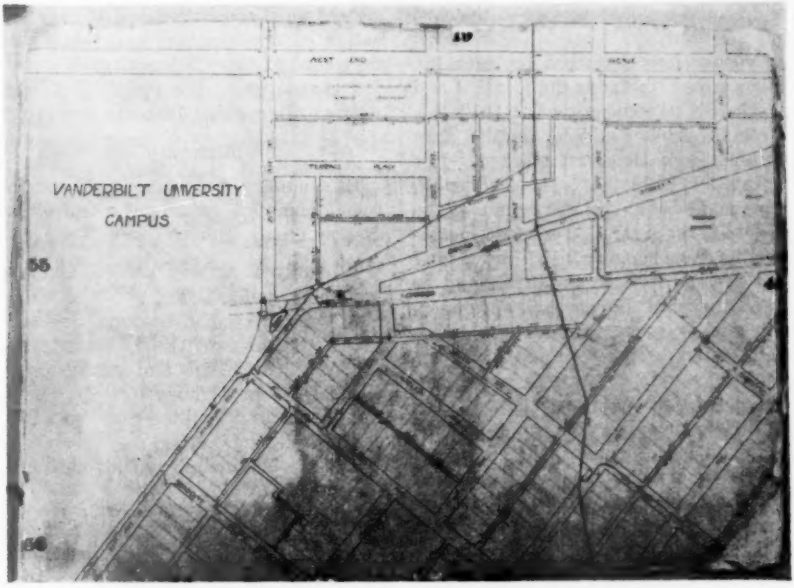

FIGURE 8.—Specimen sheet of 100-ft. scale schematic plans.

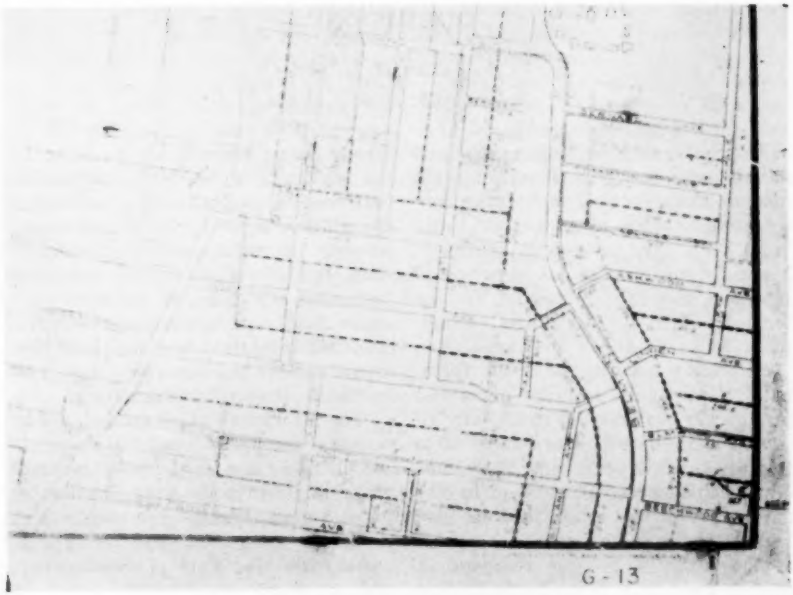

FIGURE 9.—Enlarged corner of 400-ft. scale schematic plans.

tion, would be an expansion of the card indexes, with the location of the service connections described for each lot. When asked "what is the location and depth of the connection for 1612 Doe Street?," what could be simpler than flipping over the card marked "Doe Street-1600 to 1620"? The reply could come right back, "In the center of the alley at the rear. Ten feet northwardly from your south line, and 7 feet down." Also on the card could be listed the plan number and file index, for any necessary reference to detail. This system is being started in a very small way with the sewers now being completed. If it is successful in the small way, maybe more funds can be budgeted for its expansion.

The opportunity has been provided to visit with the engineering departments of several towns and cities. Some were found to be far better; others, surprisingly, far worse. One place was decided to have the perfect system until someone asked for the location of a connection and there was no record of there being a trunk sewer for connection. We didn't feel like visitors after that. Just like home!

Summary

In summary, the main points constituting complete records of a collection system are as follows:

1. Easily filed and indexed survey and construction notes.
2. Complete construction record plans with all data clearly shown.
3. Adequate filing and storage provision for record plans.
4. Accurate, simple, and speedily usable indexing.
5. Easy maintenance of all files and indexes.

That's all there is to it. Simple, isn't it? But why are there so many places without such a system of records?

DISCUSSION

By Lloyd D. Knapp

City Engineer, Milwaukee, Wis.

Mr. Stallings is to be congratulated on his excellent paper outlining the modern methods used in keeping construction records of sewers in Nashville, Tenn. He deserves sympathy in his trials and tribulations in trying to interpret the early plans he has described and in the difficulties encountered where plans are not available.

Milwaukee has indeed been fortunate. Reasonably accurate plans and profiles are available for practically all sewers, none of which are believed to be more than 80 years old. Elevations have been recorded in relation to city datum, which was established in 1836 and has been in use ever since. All of the early plans were redrawn on tracing cloth as a WPA project. The present plans are drawn on standard sheets either 24 in. by 36 in., 18 in. by 24 in., or 12 in. by 24 in. The plans are filed in conventional drawer files. In addition to the inspector's notes and reports, an engineering crew takes the flow line elevations at all manholes, measures the distances between manholes, and also checks the center-line location in relation to street lines. The construction tracings are then corrected to show this information.

The Milwaukee plans are indexed by a very complete Kardex system, in which there is a card for every block of every street in the city. The number of each plan of each sewer in that block is listed. Also shown are the type of sewer, the size, date of construction, etc.

For general reference, a set of wall

maps drawn to a scale of 300 ft. to the inch is maintained. There are 17 maps in a set and each map measures 36 in. by 54 in. These maps show to scale all sewers and manholes in the city and are usually mounted on thin plywood or masonite. A set is kept at each of the three sewer yards and another set in the general office. They are invaluable for general reference and the repair supervisors and troublemen use them constantly.

An atlas system is used for keeping track of wye and tee connections and for locating the end of house sewers at the curb line. The sheets are 30 in. by 30 in. and the street and lot lines are drawn to a scale of 60 ft. to the inch. The set includes some 30 books, each containing approximately 30 sheets. Sanitary sewers are shown in red, storm sewers in blue, and combined sewers in black. The elevation of the sewers is not given, but the "as built" location of all wyes and tees is shown in relation to the manholes. The location of the sewers is shown only if the sewers are close to the curb lines or street lines.

When the house sewers are built from the mains to the buildings, the permit number and date are given and as soon as possible the house sewers are added to the sheet. It is the policy in Milwaukee for the city to construct house sewers from the mains to a point 2 ft. back of the curb line at all vacant property just prior to paving. This, of course, is to prevent unnecessary cuts in the pavements. These stubs are also shown on the atlas sheets and the location given at the curb line as determined by the inspector's measurement.

In cases where the plumber cannot readily locate the connections, the sewer line is checked with an instrument known as the "wyeget." This is a flat boat-shaped instrument, which is pulled through the sewer. The wyeget has a flexible arm on each side and one on top. As the instrument is pulled through the sewer a small electric cable is trailed behind. This cable passes through a set of rollers, which actuate a measuring device that records distances to the nearest 0.1 ft. The cable is connected to storage batteries. When the wyeget reaches a wye or tee, one of the flexible arms flies upward and makes an electrical contact, which rings a buzzer or a bell. The buzzers and bell are of different tones, according to whether the connected arm is on the right, left, or top of the wyeget. Connections can be readily located within 6 in. The sewer to be checked is first flushed. Then a rubber ball, to which a light cord is attached, is floated through the sewer. The cord, in turn, is used to pull through a light galvanized steel cable, to which the wyeget is attached. This steel cable is wound on a small winch so that the wyeget can be pulled slowly and steadily. Where an error has been made it has been found that usually more than one connection is affected. Thus, the use of the wyeget will accurately check the entire run of a sewer between manholes.

Records of the condition of the sewers are also believed to be important and are accumulated in several ways. At the main field office, one of the clerks keeps a record of all complaints received. Most of these complaints cover such routine matters as clogged catch basins, loose manhole lids, clogged house sewers (the responsibility of the property owner), leaky basement walls, plugged downspouts, diamond rings lost in the toilet, etc. But there are also more serious complaints covering surcharged or clogged sewers, flooded creeks, etc. Records of complaints of this type are forwarded to the design division, where they are filed in a card system and prove invaluable when a system is being redesigned. These records are available for more than 15 years.

Two examining crews, consisting of

a foreman and two men, are also maintained. These crews are equipped with special clothing and equipment and have been given special training. Most of the time both crews are busy on assigned tasks, but whenever possible they examine sewers on a routine basis. The men crawl or walk through all sewers 30 in. or more in diameter, water conditions permitting. Smaller sewers are examined by means of mirrors and flashlights. Reports indicate the structural condition of manholes, the material of which the sewer was constructed, the condition of the joints, the location and size of cracks, depth of flow, high-water marks, presence of roots, and any other important matters. Such information is useful in determining whether flushing or cleaning is necessary.

Whenever a street is to be repaved, one of the examining crews carefully goes over all the sewers. The reports are typed on standard forms and a copy goes to the design division. Frequently, it is found that an examination report some 10 or 15 years old is already on file. These are useful for comparative purposes. On the basis of these reports, the design division determines whether or not the sewers are sufficiently sound structurally.

Milwaukee has some 50 liquid level gages. These are placed at key points in the sewer system and give the designers valuable information as to the actual hydraulic operation of the sewers. The charts are changed weekly. Five rain gages also are maintained at points to best supplement the gages of the U. S. Weather Bureau.

Adequate construction records, supplemented with complete operating records and condition surveys, are of great value to the designers and to the supervisory personnel responsible for the sewer system.

PROBLEMS OF THE GREATER WINNIPEG SANITARY DISTRICT *

By N. S. Bubbis

General Manager, Greater Winnipeg Water and Sanitary Districts, Winnipeg, Man.

This paper deals only briefly with a few of the problems that have confronted the Greater Winnipeg Sanitary District in the last few years. However, although the design and construction work of the Greater Winnipeg Sanitary District has been described in several articles, to make the problems discussed more intelligible it is necessary to give a brief description of the collection system and treatment plant, together with some of the design factors.

Greater Winnipeg is located at the intersection of the Assiniboine River and the Red River of the North. The municipalities making up the District are the cities of Winnipeg and St. Boniface, the rural municipalities of East Kildonan, West Kildonan, and St. Vital, and the town of Transcona. The area served by the District is approximately 80 sq. mi. of rather low-lying country, which is divided into three parts by the Red and Assiniboine Rivers.

The collection system (Figure 1) is of the combined type and has about 448 mi. of sewers. Prior to the construction of the treatment plant these sewers discharged into the Red and Assiniboine Rivers through approximately 30 outfall sewers. The population now served is about 300,000.

It was necessary to build intercepting sewers approximately parallel to both rivers to collect the sewage and convey it to the treatment plant. The main interceptor runs along the north side of the Assiniboine and along the west side of the Red. Due to the flat terrain and to construction difficulties, it was impracticable to build the interceptor low enough so that all trunk sewers could deliver into it by gravity. It was necessary, therefore, to construct 16 pumping stations, which operate automatically. It was also necessary to construct eight river crossings, two crossing the Assiniboine and six crossing the Red.

The original design called for all sewage to be screened and cut up before being discharged into the interceptor. This is accomplished by 24 comminutor stations, 16 of which are combined with the pumping stations. No screening is done at the main plant.

Primary Treatment Plant

The flow in the Red River at Winnipeg varies considerably from a recorded flow of 10 cu. ft. per sec. below the city to a maximum of more than 110,000 cu. ft. per sec. during the flood of 1950. On the average, with the exception of periods of drought, there is sufficient water to meet the minimum flow of from 1,500 to 2,600 cu. ft. per sec. required for dilution. Because there are no bathing beaches, no fisheries of any value, or any communities drawing their water supplies from the river downstream from the treatment plant, only primary treatment was provided initially. Provision was made, however, for secondary treatment if it becomes necessary later.

At present, treatment units involved include a detritor, two clarifiers, and separate sludge digestion in four di-

* Presented at 24th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; St. Paul, Minn.; Oct. 8–11, 1951.

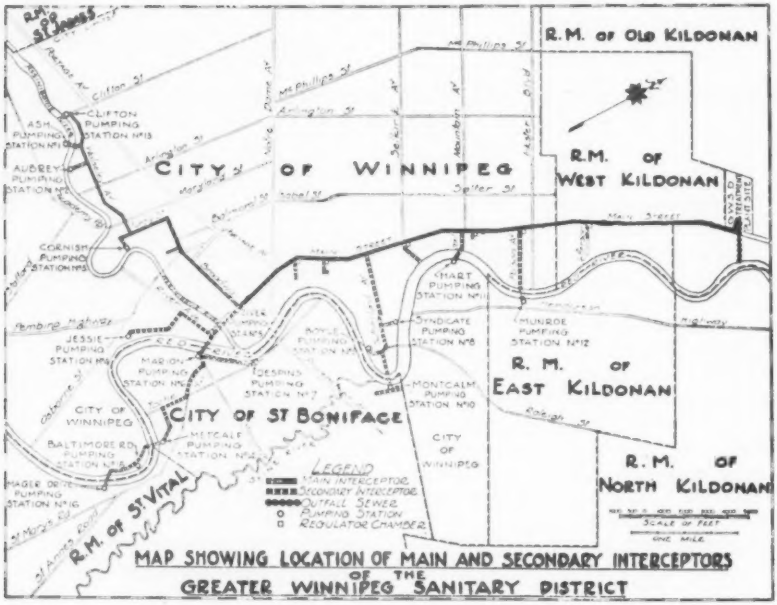

FIGURE 1.

gesters. A flexible piping system enables the four digesters to be operated as primaries, or two as primaries and two as secondaries. Heating coils are installed in all digesters; two have two turbo-mixers each. The digested sludge is elutriated with clarifier effluent to reduce its alkalinity, then vacuum filtered after conditioning with ferric chloride. The sludge cake is dumped on open piles for storage and ultimate disposal. The plant flow diagram is shown in Figure 2.

The plant was designed (1935) to serve immediately an equivalent population of 278,000 and capable of being enlarged to serve 585,000. It was estimated that the original plant would be adequate to 1945. However, as a result of World War II and the increase in industrial activity, particularly the packing industry, certain sections of the plant became overloaded by 1942. A 1947 report to the Provincial Sanitary Control Commission recommended enlarging the District's works. In 1950, a firm of consulting engineers was engaged by the District to prepare plans and specifications for this work. Only the steel shortage has so far prevented the construction from going forward. The plans include construction of an additional 145 ft. diameter clarifier and four additional 80-ft. diameter digesters. A number of pumping and comminutor stations also are to be enlarged.

Collection System Problems

When the original design work was being done in 1935, careful consideration was given to various kinds of screening and pumping equipment. It was felt that pumping unscreened sewage would prove difficult and the installation of ordinary screening devices at each station would be cumbersome and expensive. It was finally decided to use comminutors, a comparatively recent development at that

time. As a result, 24 of these units, ranging in size from 10 in. to 25 in., were installed.

As was to be expected with any new development, certain difficulties were experienced at the start. However, following careful studies, certain changes were made in the approach channels and in the machines themselves, which solved most of the difficulties.

As already mentioned, the sewers in the District are of the combined type. Although practically no difficulty has been experienced with those stations handling domestic sewage, considerable trouble is still being experienced in stations where quantities of grit, bricks, bottle caps, steel wool, paunch manure, pigs' toe nails, etc., are received. In several stations quantities of rags cause trouble by forming "ropes" as they pass through the comminutors, which "ropes" later cause the pumps at the station or the main plant to plug.

A continuous campaign to prevent dumping of such materials into the sewers is helpful. The District has also found it advisable to establish a thorough maintenance program to keep the machines in shape. A force of 10 men and three trucks do this work, 2 light trucks with 3 men and one heavy truck with 4 men. Although the stations are automatic, they are visited and checked every day by one of two service crews. The third (repair) crew does any major work required, including changing of machines and repair work on other equipment or the station itself. It might be noted that 3-man crews are used chiefly as a safety precaution.

There are some 33 pumps installed in the stations. Trouble due chiefly to clogging with rags has been pretty well overcome by changing some of the impellers and by keeping the comminutors in good shape.

It was found that condensation was troublesome in the pumping stations,

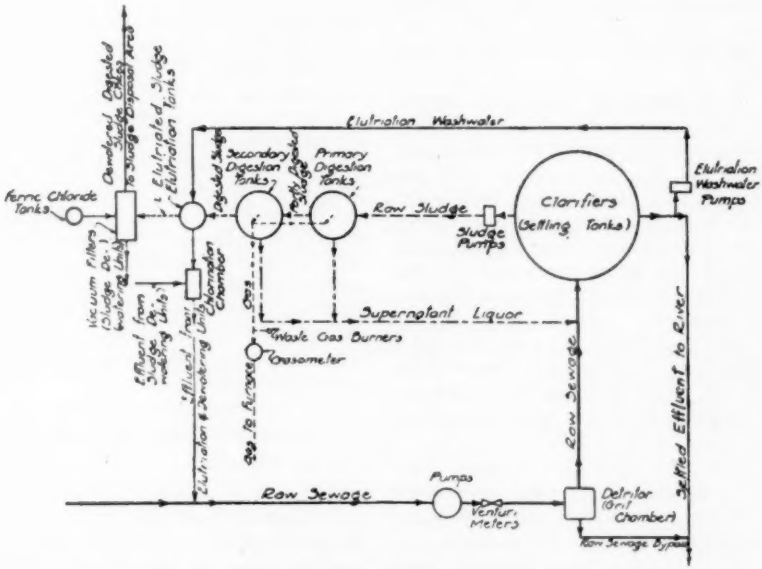

FIGURE 2.—Flow diagram for Winnipeg sewage treatment plant.

particularly in the wintertime. This was overcome wherever possible by the installation of small ventilating fans.

River Crossings

There are two crossings under the Assiniboine River and six under the Red River. These lines are of 10-in. and 12-in. Universal pipe; three are multiple crossings. The lines were constructed very simply during the winter by assembling them on the ice and then lowering them to the river bed. Several breaks have occurred in the lines where movement of the banks has taken place. One river crossing developed several breaks caused by scour of the river bottom and had to be repaired by a diver. The underlying strata in this area are alluvial clays varying in depth from 10 to 100 ft. overlying a limestone deposit. The river banks are subject to considerable movement and the bed itself to scour.

Following the flood in the spring of 1948, four of the crossings had to be repaired. When two of these were again badly damaged during the 1950 flood, it was decided to replace them with either flexible cast-iron or steel pipe.

The consulting engineers recommended a steel line with welded joints, coated and wrapped on the outside and lined on the inside with coal tar enamel, and anchored at both ends. A.W.W.A. specification 7A.6 was used, with the exception that an enamel modification was used which enabled the pipe lining and coating to withstand temperatures down to $-40°$ F., although movement of pipe was prohibited at temperatures lower than $-5°$ F. The specifications called for the pipe to be laid in a trench with a minimum cover of 4 ft.

Only the Montcalm crossing, two 24-in. diameter lines, was proceeded with last winter. This proved to be an interesting installation. The contractor planned the work very carefully and carried it out most competently. The work was done during the winter so as not to tie up river traffic and because the depth of the river is about 6 ft. less than in summer. In order to assure himself of being able to use heavy equipment, a wood pile trestle was constructed. Ice was built up to a depth of several feet by flooding. The trench was dug by clamshell. The river section of the line, about 500 ft. in length, was laid out on the ice, assembled to conform to the contour of the trench, and the joints were welded, coated, wrapped, and lined. The line was carefully checked visually and by an electrical "holiday detector" to locate any breaks in the enamel. The ends were capped and the entire section was tested by compressed air.

Following satisfactory tests, the pipeline was lowered into the trench. This was accomplished by placing six draglines on the trestle. The line was then rotated 90° from the horizontal to the vertical and the pipe lowered slowly into the river by gradually filling it with water to sink it. Levels and alignment were carefully checked to make sure the line was in the correct position, after which another pressure test was made. The same procedure was followed with the second line.

Even though this work was carried out throughout the severest portion of the Canadian winter, a good job was done by devising and making up various equipment to heat and protect the work as it proceeded. However, work such as this, which calls for applying enamel coatings or even using enamelled pipe fabricated in the shop, should not be done under winter conditions similar to those encountered whenever it can be avoided.

Treatment Plant Problems

Digester Capacity

The plant as originally designed provided slightly more than 1 cu. ft. of digester capacity per capita. For the first few years this proved satisfactory and two of the digesters were oper-

ated as primaries and two as secondaries. By 1942, however, the load had increased to such an extent that all four digesters had to be used as primaries. This increase in load was caused primarily by packinghouse wastes.

Experience has shown that at least 2 cu. ft. per capita should be provided. The new digesters will add 600,000 cu. ft. of capacity to the existing 297,000 cu. ft. It is estimated that at the present rate of growth this will suffice to 1965 for an estimated population of 360,000.

Two of the digesters have turbomixers and 3-in. diameter steel pipe heating coils with 1,050 sq. ft. of heating surface. The other two digesters have heating coils with 700 sq. ft. heating surface. Experience has definitely proved that the mixers and heating coils improve the operation of the digesters and the proposed additions will all be so equipped.

Industrial Wastes

Considerable difficulty and expense have been caused both in the collection system and the treatment plant by industrial wastes, chiefly from packing plants and abattoirs.

Prior to the construction of the treatment plant, all industrial wastes which could physically be discharged to the sewers were disposed of in this fashion, and so into the rivers. As a matter of fact, it was this condition which turned the rivers into virtually open septic sewers during the low-water years in the early 1930's and finally resulted in the organization of the Greater Winnipeg Sanitary District. It is understandable that such practices were difficult to break, especially where the only alternative meant installation of costly equipment to separate the objectionable wastes, and further cost in disposing of them by other means.

The abattoirs and meat packing plants were the greatest offenders. The fable of their efficiency, to the effect that "they save and use everything in the pig but the squeal," is unfortunately somewhat exaggerated. The discharge of large quantities of paunch manure, grease, pigs' toe nails, bones, etc., resulted in clogging the sewers and plugging the comminutors and pumps. On reaching the plant, the sewage caused further trouble. Frequently, a blanket has formed on top of the clarifiers, which in cold weather would freeze. In the digesters a scum blanket several feet thick has formed; this has been difficult to break up and frequently has required the emptying of the digesters.

Although efforts had been made periodically to obtain the cooperation of the plants, results were not too good; during and for some time after World War II the shortage of equipment was used as an excuse. Finally, it was decided that this condition could be tolerated no longer. Representatives of the various plants were called to a meeting and informed of the steps the District proposed to take. The companies would be given a specified length of time to put their plants in order and to apply for a license to discharge packing and slaughterhouse wastes into the sewers subject to the District's regulations (see Appendix I). Further, to make absolutely sure of compliance, the District would construct screen chambers of its own on the plant sewers, in which screens and baffles would be installed.

If any plant continued to operate without a license it would be subject to court action; to make sure that the District had the necessary legal powers to enforce its regulations, the District's Act was amended in the spring of 1950 by the Provincial Legislature.

All of the 10 plants interested realize that the District meant to proceed with its plans; all have applied for licenses and are proceeding with plant changes and installation of equipment. In about one-half the plants, the District's screens have been incorporated

with structures being built by the packers. It is expected that by the end of the year this part of the problem will be well on the way to solution.

Other types of wastes have also caused trouble, but not to the same degree. Discharge of oil wastes and mercaptan from refineries has taken place periodically. Gasoline and fuel oil have found entry into the sewer system from leaking tanks or by accident, creating a dangerous condition. Cinders, chips from stone cutting works, and acid from a bentonite processing plant have also made trouble.

Sludge Handling and Removal

As previously mentioned, the sludge is digested, elutriated, and vacuum filtered. Due to Winnipeg's location, chemicals have to be shipped in from long distances, thus greatly increasing the cost. This was one of the factors in adopting the elutriation process. The cost of ferric chloride has increased from 4.3¢ per pound in 1940 to 8¢ per pound in 1951. Putting it another way, the cost of ferric chloride per ton of sludge (dry solids) filtered, increased from $2.65 in 1940 to $6.72 in 1951.

In addition, the cost of removing the sludge from under the dumping trestle has also been increasing. Attempts have been made to encourage farmers, market gardeners, and landscape gardeners to remove it, but the results have not been too successful. One of the reasons has been the difficulty in loading the sludge, which can only be handled during the dry parts of the summer. Recently the Parks Board has been cooperating by using some of the sludge experimentally. In 1950 a contract was let to remove 990 cu. yd. of sludge at 65¢ per yard.

Altogether the cost of elutriating, filtering, and removing the sludge has risen from $13.80 per ton (dry weight) in 1944 to $23.10 in 1949.

Having in mind these rising costs and the fact that increasing the plant capacity would also require increasing the elutriation and filter equipment, the consultants gave consideration to lagooning as an alternative. This has been done successfully in a number of American plants. However, it was felt that local conditions might not be entirely suitable to lagooning and it might be advisable to experiment with lagooning before a definite decision was made as to which method would be used finally in the Winnipeg plant.

As a result, a contract was awarded for the construction of six test lagoons and two drying beds. The test lagoons are 100 ft. by 150 ft.; three are provided with underdrains. The two drying beds are 50 ft. by 150 ft.

There is an unusual feature about the lagoons. Normally lagoons are not provided with underdrains. However, in view of the very impermeable characteristics of the Red River clay, it was felt that it might be advisable to experiment with some underdrained lagoons. As it will be possible to experiment with the test lagoons for at least two seasons before a decision will have to be made, it will be possible to obtain sufficient data to determine the feasibility of lagooning sludge in the area.

Concrete Disintegration

The clay subsoil in the Winnipeg area is a most active alkaline soil containing the objectionable sulfates of sodium, magnesium, and calcium. All concrete sewers prior to 1932 were built of Portland cement concrete. In numerous cases when the soil adjacent to the sewers contained considerable quantities of these alkali salts, the concrete disintegrated badly. The District, therefore, adopted a policy of using an alkali-resisting cement in all concrete laid below ground and no trouble has developed.

However, the District has experienced trouble from concrete disintegration of another kind. In the fall of 1940 disintegration of the surface of the concrete walls and columns in the

outfall chamber was first noted. This condition was observed very closely for a period of years, until in 1946 it was obvious that the disintegration had proceeded to such a point that extensive repairs were undertaken (see THIS JOURNAL, 21, 1, 144; Jan., 1949). Tests indicated that the cause was bacterial conversion of sulfur compounds in the sewage to sulfuric acid, which in turn reacted with the concrete. Previous tests for the presence of hydrogen sulfide in sewage from different parts of the collection system and treatment plant had indicated that quantities as high as 2 p.p.m. reached the plant. The bulk of this sulfide was found to come from the sewers serving the packing plants and concentrations as high as 7 p.p.m. were noted. An investigation to determine whether the solution to this problem could be found by the use of chlorine showed that this method was not economically practical.

The concrete repairs of the outfall chamber proved to be a difficult and costly job. It was thought that since the new concrete was very dense, it would solve the problem. However, this was not the case and the concrete is again showing signs of disintegration.

As a result, further investigations were made. Efforts were made to apply protective coatings of various kinds to the walls of the chamber, but without any great success. Plastic paints, bituminous coatings, silica coatings, and various types of mineral paints were tried; none proved effective. Part of this lack of success may have been due to the fact that the walls of the chamber could never be thoroughly dried before applying the coating.

It was finally decided to investigate the use of ciment fondu, a luminite cement. These tests (see Appendix II) indicated that use of this cement with a good quality sand should provide a coating that was resistant to dilute sulfuric acid and would also stand up under the abrasion of flowing sewage. It is planned to carry out this repair work during the winter of 1951–52.

A similar type of corrosion was noted on the inside of the concrete clarifier walls just above the water line. Here again, disintegration has occurred at a point where spray action takes place and is probably due to the same cause. Some test repair patches made during 1950 stood up well; therefore, the two clarifiers were repaired during 1951 by plastering with ciment fondu.

Outfall Sewer

The original outfall sewer, which is 90 in. in diameter, was constructed in two sections. The first, 1,572 ft. in length, was constructed of monolithic alkali-resisting cement concrete. The second section, closest to the river, is 495 ft. in length. Because it was located in unstable soil, it was constructed of corrugated-iron, asphalt-covered pipe.

In July, 1950, following the flood, a depression was discovered some 150 ft. west of the eastern end of this section. This indicated that some damage had been caused to the pipe.

It was not possible to make a thorough examination of the damage until the high water receded in the fall, but it was not anticipated that the repair would be very difficult. The engineers of the firm originally supplying this pipe were consulted and it was decided to effect the repair by uncovering and reassembling any of the pipe that had been buckled. Work was started the beginning of November, 1950. However, by the end of November, when the pipe had been uncovered, it was found that a 60-ft. section of the pipe had risen about a foot probably due to flotation, and that a number of sections had telescoped due to failure of the bolts. The bolts used were not standard galvanized steel, but were made of Z metal to resist corrosion. In addition, considerable corrosion was found to have developed in a number of plates

at the seams where they joined one another.

In view of these conditions, it was felt that serious consideration would now have to be given to the replacement of this section of the pipe. The District's consulting engineers recommended that the entire length of corrugated-iron pipe be removed and replaced with a monolithic alkali-resisting concrete sewer. This sewer was to be placed on and anchored to a wood pile foundation. In addition, due to the disintegrating action which had taken place on several concrete structures, it was recommended that the inside of the pipe be coated with various linings. As an experiment, the 185-ft. section nearest the river was lined with a 2-in. layer of ciment fondu grout; a plaster coat of the same material was used for the next 100 ft.; a 40-ft. section was coated with a brush coat of ciment fondu; smaller sections were coated with various materials, such as ciment fondu grout applied by guniting, bituminous asphalt, water glass, heresite, and brush coat of lumnite cement; and a 60-ft. section was also left uncoated for control. This pipe will be watched very closely during the next few years to determine which of the linings is most suitable for the prevailing conditions.

Flood Pumping

Experience with the Winnipeg Flood of 1950 and observations of the Kansas City flood of 1951 have demonstrated the importance of sewage pumping stations in flood fighting. This is an important subject and merits more consideration that can be given in this paper. Attention should be called, however, to a few salient points.

It is obvious that dike or levee construction, to be effective, must be coordinated with well-designed, well-constructed, and well-operated pumping stations. When electric power is used, the provision of uninterrupted supply is important. In the design, consideration should be given to the always present likelihood of the levees giving way or being topped, resulting in the stations being flooded. Rapid recovery and rehabilitation will depend to a considerable extent on how quickly these stations can be put back into service.

APPENDIX I

EXCERPTS FROM BY-LAW NO. 38, PROHIBITING THE DISCHARGE INTO SEWERS OF CERTAIN DETRIMENTAL WASTES

2. No person shall discharge into any sewer, within or entering the District, any of the following;

(a) Paunch manure or intestinal contents from horses, cattle, sheep, or swine.

(b) Any animal grease or oil.

(c) Pigs hooves or toenails.

(d) Any animal intestines or stomach casings.

(e) Bones.

(f) Hog bristles.

(g) Hides or parts thereof.

(h) Any animal fat or flesh in particles larger than will go through a quarter inch screen.

(i) Horse, cattle, sheep, or swine manure.

(j) Poultry entrails or poultry heads, feet, or feathers.

(k) Fleshing and hair resulting from tanning operations.

3. No person shall discharge into any sewer, within or entering the District, Slaughter House or Packing House waste. Provided that any Slaughter House or Packing House which passes all of its Slaughter House or Packing House waste through,

(a) A grease skimmer, of such type and capacity as may be approved by the Chief Engineer of the Corporation;

(b) A sedimentation tank of such type and capacity as may be approved by the Chief Engineer of the District, so constructed that no solids shall escape therefrom, save such as may pass through a quarter inch screen placed at the street line;

may be given a permit or license by the Corporation to discharge such Slaughter House or Packing House waste into sewers, within or entering the District, but the only sewer connection, other than for lavatory, wash room or kitchen wastes, or clear water approved as such by the Chief Engineer of the Corporation, to the said Slaughter House or Packing House premises, shall be through such grease skimming equipment and the sedimentation tank aforesaid.

4. It is further provided, that any Slaughter House or Packing House having a maximum killing capacity of less than fifty units per hour (it being computed that a hog equals one unit, a sheep or calf two units each and other cattle or horses two and a half units each) may be given a license or permit to discharge wastes to a sewer, within or entering the District, if it installs such vibratory screens or other screens or devices as may be approved by the Chief Engineer of the Corporation . . . , but in any such case no license or permit shall be given if there be any manhole or opening into the sewer system between such approved vibratory screen or other screen devices and the street sewer; nor shall there be any means by which the said vibratory or other screens or devices may be by-passed with sewage other than toilet, wash room or kitchen waste or clear water approved as such by the Chief Engineer of the Corporation.

5. Any license or permit to discharge Slaughter House or Packing House waste into a sewer, within or entering the District, may be cancelled by resolution of the Board at any time after sixty days notice. If any person who has been given a permit or license to discharge Slaughter House or Packing House waste into a sewer within or entering the District, shall fail, in the opinion of the Chief Engineer of the Corporation (whose opinion shall be final) to operate efficiently the equipment installed and approved by the Chief Engineer of the Corporation, for the treatment of wastes from Slaughter Houses and Packing Houses, or shall by-pass such equipment, so approved and installed, with Slaughter House or Packing House waste, the Administration Board may forthwith by resolution cancel such permit or license to discharge Slaughter House or Packing House waste into any sewer within or entering the District; and no such permit or license shall be renewed or re-issued to such person for a period of six months from the date of cancellation, and then only upon such person installing such further equipment or giving assurance by bond or otherwise, for the efficient operation of the equipment for treating such Slaughter House or Packing House waste that may have been installed or may be ordered to be installed in the future, as shall be satisfactory to the Administration Board.

APPENDIX II

Experimental Work on Use of Ciment Fondu to Prevent Concrete Disintegration

The only serious disintegration of concrete has occurred in the walls and supporting columns in the effluent gate chamber. Efforts were made to apply protective coatings of various sorts to the walls of this chamber, but without any great success. Plastic paints, bituminous coatings, silica coatings, and various types of mineral paints were tried, but none of these coatings proved

effective. This is probably due to the fact that the surfaces of the walls were wet and it was not feasible to dry out the concrete. However, even if the concrete walls were dry when applying any of the above-mentioned coatings, it is believed they would not have been effective, due to the abrasive action of mineral particles in the sewage pouring into the chamber.

The main factor contributing to the disintegration of the concrete in this chamber is believed to be the spray condition that is always present. The sewage falls into the chamber with about an 8-ft. drop, causing great turbulence. A fine mist or spray is deposited over the walls above the normal water line. This gives rise to a coating of scum and provides a good medium for the growth of bacteria. Some of these bacteria, especially *Sporovibrio desulfuricans*, convert sulfur compounds into sulfuric acid, which eats away the concrete.

By 1944, after 7 years of operation, the disintegration in the effluent chamber had become so bad that extensive repairs were undertaken. The deteriorated concrete was chipped away to good concrete and replaced with concrete applied by the gunite method. It was thought that since this new concrete was very dense, it would solve the problem. However, this was not the case. The concrete is again showing signs of disintegration.

In an attempt to find a coating that was resistant to dilute acid and also would stand up under the abrasion of flowing sewage, it was suggested that the use of ciment fondu be investigated. As described in the literature, the composition of ciment fondu is as follows:

SiO_2	5.09%
Al_2O_3	39.04%
Fe_2O_3	12.90%
FeO	4.06%
TiO_2	1.61%
CaO	37.25%

The predominant compound in ciment fondu is the mono-calcic aluminate (Al_2O_3CaO); hence, ciment fondu is known as an aluminous-type cement, in order to differentiate its type from the Portland cements. The chemical reaction during setting and hardening is different from that of Portland cement. The point to note is that Portland cement liberates lime on hydration, whereas ciment fondu liberates alumina, both of which remain in the free state. Alumina is a relatively inert material, hence, ciment fondu is relatively immune to common chemical attacks by such things as sea water, neutral sulfates, sulfur gases and fumes, sewage, dilute acids, etc. This is not the case with the lime liberating Portland cement. It is the absence of free lime and the stability of the aluminates formed which render ciment fondu immune from attack by such a wide variety of chemical agents.

The setting time of ciment fondu is less than that of Portland cement. Under normal circumstances, initial set is in about 3½ hours and the final set about 2 hours later. One great advantage of ciment fondu is its early strength. Strength of 6,000 lb. per sq. in. at 24 hr. is about the average, with 8,000 lb. and up at the end of 7 days. Due to the fact that ciment fondu combines with twice as much water during hydration as Portland cement, less evaporation of excess mixing water takes place, making a denser and less porous concrete. Also, due to its slow setting time, ciment fondu is admirable for use as a coating. The only precaution to be taken is that the surface must not be allowed to become dry for 24 hr. after mixing the concrete. Ciment fondu bonds readily to either old or new cement, be it Portland or ciment fondu. Its early strength makes it possible to remove forming after 24 hr.

To compare the resistance of ciment fondu and Kalicrete cement to acid, the following laboratory test was carried out. Blocks of concrete were cast up of various combinations of sand and cement. The blocks were then im-

mersed in an aqueous solution of sulfuric acid, and the degree of deterioration of the concrete noted. The combinations were as follows:

1. Ciment fondu, neat.
2. Ciment fondu—Bay City sand blast sand.
3. Ciment fondu—Ottawa test sand.
4. Kalicrete—Ottawa test sand.
5. Kalicrete—Bay City sand blast sand.
6. Ciment fondu—ordinary mortar sand.

All specimens except the neat ciment fondu were in mixtures of 1 to 3. Five blocks of each combination were used, immersed, respectively, in 1, 2, 3, 5, and 10 per cent solutions (by volume) of c.p. sulfuric acid. The two strong acid solutions were included to get a highly accelerated rate of disintegration. The Bay City and the Ottawa test sands are special silica pure sand, completely resistant to acid action. The ordinary mortar sand was the usual type supplied to the trade and is more or less acted on by acid.

The most striking effect was the rapid rate at which the Kalicrete mixtures deteriorated. After 7 days, the Kalicrete mixtures were completely disintegrated in the two strong solutions and showed considerable corrosion in the weaker solutions. The ciment fondu mixtures stood up very well, and after 11 months were not completely destroyed in the two strong solutions. In the weak solutions, the degree of corrosion was comparatively slight. The ciment fondu-ordinary sand mixture stood up quite well, although it showed a greater degree of deterioration than the silica test sands.

The tests indicated that a 1:3 mortar of ciment fondu and a good quality silica sand should provide a coating that would resist acid corrosion in chambers and tunnels through which sewage flows.

A FUNDAMENTAL APPROACH TO THE ACTIVATED SLUDGE PROCESS *

II. A Proposed Theory of Floc Formation

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One of the fundamental mechanisms essential to the activated sludge process is the formation of floc. Up to the present time very little research has been concerned with floc formation. Yet, it is on the basis of floc formation that the success of the activated sludge process depends. It is the purpose of this paper to present a proposed theory on the formation of activated sludge, based on the observations of the author coupled with the research of previous investigators.

Previous Work

The theory of activated sludge was in considerable doubt before Butterfield (1) showed that it was possible to isolate a bacterium from normal activated sludge which was capable of producing a floc. Butterfield felt that this bacterium, *Zooglea ramigera*, secreted a gelatinous matrix, in which the bacteria resided. This gelatinous matrix was observed in photomicrographs of normal activated sludge.

In 1939, Heukelekian and Littman (2) confirmed the work of Butterfield. This was followed by more extensive work by Wattie (3). These investigators felt that the bacteria were bound together by a gelatinous material surrounding each cell.

Also in 1939, Rudolfs and Gehm (4) reviewed the various theories of colloidal adsorption in the aerobic treatment processes. The works of Dunbar, Dienert, Theriault, Cavel, Buswell, Baly, Lumb, and many others, showed that the colloidal matter in sewage was adsorbed by the slimes, but none agreed on the mechanisms involved. Theriault believed that the gelatinous matrix of activated sludge was a biozeolitic substance and that the organic materials were adsorbed onto the sludge by an ion exchange process. Electrical charge was the theory of Cavel and others. Cavel felt that the slimes were positively charged, as they adsorbed negative colloids. This idea was disproved by Buswell, who showed that both the colloid and the slime had negative charges. Baly and Lumb advanced beyond this with the idea that the more negatively charged floc adsorbed the less negatively charged colloids.

Aside from the work of these investigators, very little has been done to show how the bacteria actually come together and form the floc, or how they adsorb the sewage colloids once the floc has formed.

If the activated sludge floc was made primarily by one species of bacteria, as set forth by previous investigators, it might be assumed that the floc formation was a special property of that specific organism. The previous paper (5) in this series showed that there were several different species of bacteria which were capable of forming a floc when aerated in a suitable nutrient medium. These organisms gave

* Presented at 24th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; St. Paul, Minn.; Oct. 8–11, 1951.

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B.O.D. removals from 66 to 88 per cent in a synthetic sewage whose composition was comparable to normal domestic sewage. This indicated that the flocculation mechanism was a general property of bacteria and was not limited to one species.

Microscopic Observations

Microscopic observations were made on hundreds of samples of sludges for the purpose of determining the physical characteristics of normal activated sludge. It soon became obvious that activated sludge formed from sewage contained too many different organisms and too much extraneous material to make significant observations possible. Pure bacterial cultures were employed in soluble substrates to eliminate these two important variables. Observations were made from the time when the bacteria were inoculated into the nutrient substrate until the floc was formed and operating properly.

At first, the bacteria were quite dispersed, as in a normal liquid culture. After several hours of aeration the bacteria began to floc together. This was not apparent without the aid of the microscope. The medium was cloudy, but without visible floc particles. As the aeration period increased, the clumping also increased. Where it had been possible to distinguish each cell in the small flocs, it became impossible to observe the individual cells except around the edges of the dense masses. After repeated feedings and several days of aeration, the pure culture flocs were fully developed and like floc formed from sewage.

The above procedures were repeated many times using pure cultures of *Zooglea ramigera, Escherichia intermedium, Nocardia actinomorpha, Bacillus cereus, Aerobacter aerogenes,* and others, in addition to using sewage-seeded synthetic substrates. In all cases it appeared that the floc was formed in the same manner. The bacterial cells were attracted to each other and were joined together by their capsules. This capsular material did not expand in the early stages of floc development. New cells built up on the other bacteria and the floc was soon nothing more than a large mass of bacteria separated by their capsules. This bears out the observations of Heukelekian and Littman (2) and Wattie (3).

In the use of soluble substrates, there was not at any time, in any of the cultures, the appearance that the bacteria were residing in a large zoogleal or slime matrix. The cells were always right next to each other, with only capsular material appearing between adjacent cell walls. When sewage or synthetic substrates containing insoluble materials were used, the floc had the appearance of bacteria residing in a zoogleal or slime matrix.

Method of Attack

As a result of these observations, it was felt that the surface of the bacteria was the key to floc formation. A thorough study was then made to determine how much was known about the bacterial surfaces and how this information could help in explaining floc formation.

The bacterial surface has attracted the interest of many investigators. Although the majority of the work has been done in relationship to the antigenic properties of specific pathogenic bacteria, it is possible to make use of much of the information.

For the most part, bacteria are regarded as colloids. Although the size of bacteria exceeds the limits normally set for colloids, the physical properties are predominantly of a colloidal nature. The principles of colloidal chemistry must be kept in mind whenever the bacterial surfaces are discussed. As it is impossible to set forth all the colloidal principles in this paper, the reader is referred to Alexander and

Johnson (6) for a complete presentation of the modern colloid theories.

Capsules

Inasmuch as all the bacteria studied were found to have definite capsules and it appeared that the bacteria were joined at the capsular surface, efforts were directed to learning the nature of the capsules, the physical and chemical properties, and the factors which affected the nature of the capsules. Dubos (7) stated that capsular production was not dependent on the bacterial strain, but was a factor of the conditions under which the culture was growing. After carefully reviewing the work of other investigators, Dubos concluded that the capsular material was a high molecular polysaccharide containing acidic, acetyl, and amino groups in varying amounts. Porter (8) and Knaysi (9) also came to the same conclusions as Dubos. In activated sludge the conditions are favorable for capsule production, as is evidenced by the large number of capsulated strains which can be isolated from the floc.

One of the chief characteristics of a colloidal system is the possession of an electrical charge and the effect of electrical charge on the system. Bacteria are predominately hydrophilic colloids; that is, water loving. The hydrophilic colloids are not greatly affected by electrical charge and are not entirely dependent on charge for their stability. Nevertheless, charge plays an important part in floc formation.

Abramson (10) found that bacteria had a definite cell potential and that the reduction of this potential resulted in agglutination of the bacteria. The reduction in cell potential was brought about by the addition of various salts to the solution. It was shown by McCalla (11), in 1940, that bacteria adsorbed positive ions from solution as a result of their negative surface charge. The adsorption of ions onto the bacteria was found to follow the Hofmeister series. *E. coli* were found by Weiss (12) to be adsorbed onto silt in a stream as the result of electrical charge. Soils high in Fe^{+++} and Al^{+++} were found to cause strong adsorption of *Azotobacter chroöcoccum*.

Thus, it may be seen that electrical charge plays an important part in the flocculation of bacteria. The chemical composition of the slime layer is believed to be responsible for the electrical charge on the bacteria. Very little is known about the chemical structure of capsular material. Although much work has been done on this problem, it was not to determine the over-all formula of the complex polysaccharide, but to determine the basic structural unit. This has resulted in the use of strong reagents capable of degrading the complex polysaccharide. It is felt that many of the so-called basic units are incorrect by virtue of the analytical techniques.

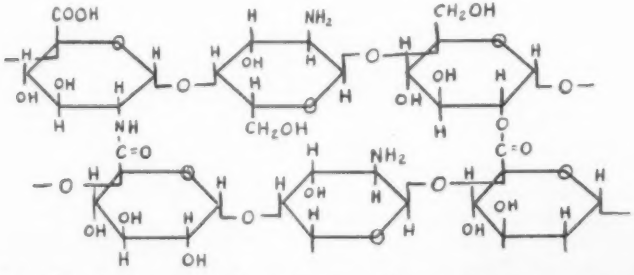

FIGURE 1.—Chemical structure of capsular material composited from various bacteria.

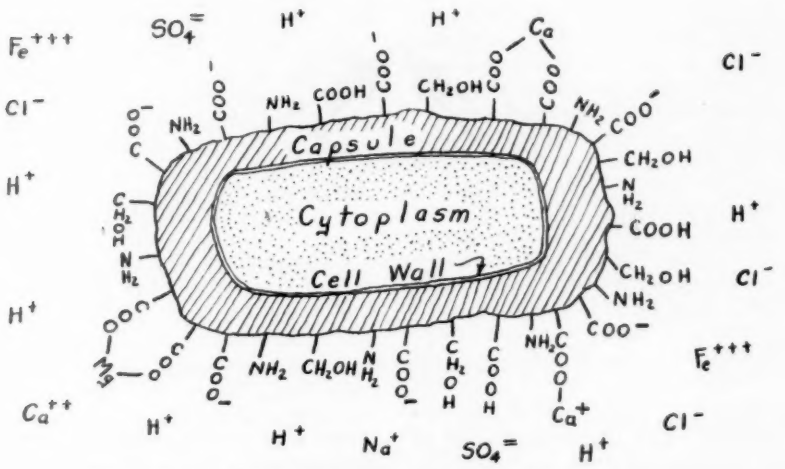

FIGURE 2.—Schematic representation of a bacterial cell in sewage.

But in spite of their shortcomings, it is possible to draw some definite conclusions as to chemical structure.

The conclusions on the capsular structure presented by Dubos (7), Porter (8) and Knaysi (9) were drawn on quite heavily, as they have collected the important data from almost every available source. These data and data obtained by Goebel (13) (14) were composited and a general capsular structure was set forth. The chemical formula of this material is shown in Figure 1. This formula does not represent the exact surface structure of any specific organism, but does contain the general components of the capsular material of the organisms which might be found in activated sludge. Although the material is predominately polysaccharide, it does have the electrical characteristics of a protein; that is, amphoteric. This satisfies the experiments of Dyar (15) (16).

In a neutral or basic solution the carboxyl group ionizes as follows:

$$-\mathrm{COOH} \rightleftharpoons -\mathrm{COO}^- + \mathrm{H}^+$$

The ionized carboxyl group gives the bacterial surface a negative charge. It can be seen from the chemical structure that the negative charge is actually a point function on the bacterial surface. If the solution is acidic, the amino group is affected as follows by ionization:

$$-\mathrm{NH_2} + \mathrm{H}^+ \rightleftharpoons -\mathrm{NH_3}^+$$

This would give the surface a positive charge. In normal activated sludge the first reaction is the only one of importance.

Theory of Floc Formation

From the preceding information and from visual observations of many different sludges, it was possible to set forth a probable theory on the formation of activated sludge floc. Two important components were found to exist in floc—bacteria and sewage colloids. Although they are discussed separately, it must be kept in mind that both the bacteria and the colloids are affected simultaneously.

As the bacteria in sewage enter the aeration unit, several rapid changes are brought about in their environment. The aeration changes the oxygen level from negative to positive, thereby per-

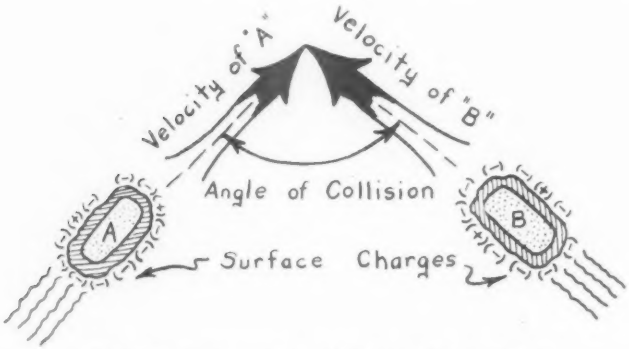

FIGURE 3.—Factors affecting bacterial flocculation.

mitting the aerobic bacteria to predominate. Agitation brought about by the aeration has a two-fold effect: (a) maintains the food concentration at a maximum throughout the aeration tank and (b) stimulates bacterial reproduction.

At first, the bacterial numbers are too small to bring about collisions between cells. But with favorable growing conditions, the bacterial numbers increase quite rapidly. As the bacteria grow, equilibrium is set up between the bacteria and the dissolved salts in the sewage. The negatively charged bacteria attract the cations in solution, but are opposed in this by the anions present. The equilibrium which results is an ever-changing equilibrium based on the magnitude of the electrical charges. The cation is actually in continuous oscillation between the carboxyl group on the bacterial surface and the surrounding anions. This is shown schematically in Figure 2. The chemically active groups are shown as point functions projecting from the bacterial capsule.

The adsorption of cations results in a reduced bacterial surface charge. With increased multiplication and with continuous agitation, the bacteria will sooner or later collide with each other. The bacteria will either stick together, as the result of the collision, or bounce off in a new direction. There are several factors which will affect the probability of two bacteria sticking on that first collision. The angle of collision, velocity of the bacteria, surface tension forces, and electrical charge all play a part in whether or not the two bacteria will stick. These forces are illustrated in Figure 3. If the surface charge on the cells is low, the angle of collision is large, the surface of contact is large, and the velocity of collision is large, the probability of the two bacteria sticking together is high.

Once the two bacteria have stuck together, a larger surface area is available for collision with a third bacterium. The over-all surface potential has been reduced by the proportion of surface area in contact. Thus, the probability of collision increases as the size of the floc becomes larger. As more bacteria collide and stick, the probability of a collision with a sewage colloid also increases. The same factors are involved here as in the case of bacterial collisions. The addition of a sewage colloid to the floc particle serves a dual purpose. The bacteria utilize the organic fraction as a source of energy and incorporate the inorganic fraction as part of the floc. This inorganic fraction adds mass to the bacterial floc. With more collisions, the floc grows until the agitation forces become critical enough to limit its size.

Discussion

The theory of floc formation as presented here is but one small phase in the over-all problem of activated sludge. In itself it is not complete; not only must the floc form readily, but it also must settle rapidly. The ability of the floc to settle rapidly will be affected by the compactness of the floc, the number of live organisms, and the mass of the floc. The compactness of the floc is dependent on the types of organisms making up the floc. If the floc is predominately small bacilli or diplo-bacilli, it will be compact. But if the floc is predominately long chained, branching, or sheathed organisms, it will tend to be loose. The latter sludge will have predominately poorer settling characteristics than the former.

The exact effect of the number of live organisms has not been evaluated, primarily because it is not possible to accurately count the organisms in the floc. Nevertheless, certain observations have been made. It appears that the greater the number of live cells, the less the tendency to form a settleable floc. Small bacterial flocs form, but they lack sufficient mass to settle. As the bacteria increase in age, the rate of dying exceeds the rate of multiplication. The floc becomes composed predominately of dead bacteria, which lose their motility and appear to become more permeable, thus making them more susceptible to flocculation and sedimentation.

The mass of the floc is very important in determining its settling characteristics. Although the pure bacterial flocs will settle, additional mass was found to be necessary for rapid settling of all of the floc. The additional mass is supplied in the form of inorganic salts adsorbed from solution and from the inorganic fraction of the sewage colloids. Approximately 20 to 40 per cent of the mass of normal activated sludge is inorganic matter (17).

As expressed here, it would seem that bacterial flocculation was brought about merely by reducing the electrical charge below the critical level and allowing the cells to come into contact through agitation. It is believed that this is the predominant reaction, but not the only one. If the flocculation was entirely electrical, it would be possible to increase the agitation forces and break up the floc entirely. This is not possible. Agitation can break up the floc to a certain extent, but not to the extent that individual cells are

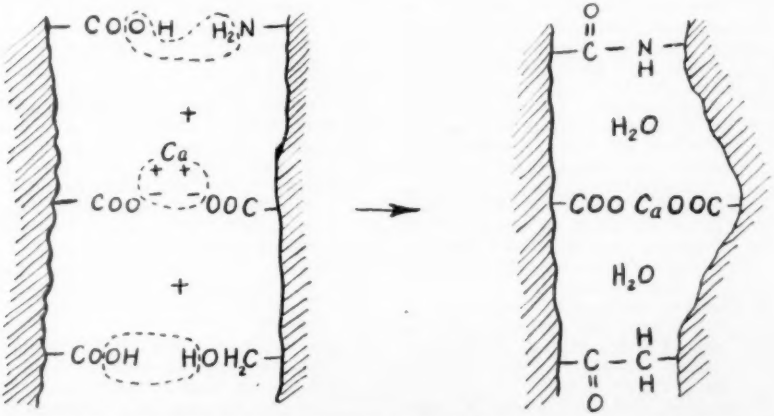

FIGURE 4.—Possible chemical reactions occurring between two bacterial surfaces.

completely obtained. It appears that the bacterial surfaces undergo direct chemical reactions, thus forming a solid bond between cells. The chemical structure of the bacterial surface offers many possibilities for chemical bonding. Because the bacteria contain the necessary enzymes for synthesizing proteins from amino acids, a peptide linkage might exist. Direct salt linkages and ester linkages are also possibilities. Figure 4 illustrates the possible reactions between two bacterial surfaces.

It can be seen that the problem of floc formation is a complex phenomenon, dependent on many variables. The theory as discussed herein sets forth the principles by which flocculation might occur and some of the factors which affect it. It is not complete and represents but one of the many fundamental factors involved in the activated sludge process. Considerable research will be required before a complete understanding of the fundamental mechanisms of activated sludge can be obtained. Without knowledge of these fundamental factors, it will be impossible to control the process at its maximum efficiency.

Summary

A theory of formation of activated sludge is proposed. This theory is based on the physical and chemical properties of the bacteria surfaces. These properties were determined largely by previous investigators and correlated with laboratory observations of activated sludge floc.

Acknowledgment

The research reported herein comprised part of a doctoral thesis at Massachusetts Institute of Technology and was made possible through a grant-in-aid from the Division of Research Grants, National Institutes of Health.

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DISCUSSION

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From time to time, it is well to review scientific theories and beliefs and to re-examine them in the light of recent progress with a view to discovering anything of importance that might have been overlooked. Mr. McKinney has re-studied the organisms responsible for purification in the activated sludge process and has isolated several zooglea-producing organisms which remove B.O.D. from synthetic sewage.

Zoogleal organisms are not uncommon and, considering the heterogeneous nature of sewage, it is not surprising to find that several varieties may exist in activated sludge. Some of the organisms, notably *Nocardia actinomorpha*, were very effective in removing B.O.D. No estimate was made of the relative numbers of these organisms. *Z. ramigera* has been most frequently reported and studied, but it still is not known which ones are most effective in purification by the activated sludge process.

Mr. McKinney mentions that most of the B.O.D. is removed within the first two hours. As is well-known, the organic matter is quickly removed by the sludge, probably by adsorption, but oxidation of the adsorbed material is relatively slow. This is brought out clearly when step aeration is used. There, nearly complete removal of B.O.D. from sewage is obtained with a 30-min. aeration period, in the presence of activated sludge. However, oxidation of this material proceeds rather slowly during re-aeration of the sludge.

The author's theory on floc formation is a slight modification of a generally accepted explanation for the flocculation of colloidal substances, especially lyophobic ones. Although most bacteria are larger than colloidal particles, they do have many of the physical properties and characteristics of colloidal systems.

The forces which cause colloidal particles to repel each other can often be modified by electrolytes in such a way as to cause flocculation. Butterfield (1) reported that, in washing zoogleal floc, the embedded bacteria freed themselves from the gelatinous matrix and moved away. The addition of nutrient broth to the dilution water prevented this dispersing action. Dilution may have caused the liberation of the bacteria by disturbing the surface charges. The nutrient broth probably restricted the changes in the surface charges and the organic matter may have served as a protective colloid to further stabilize the system.

In his stimulating re-examination of some of the fundamental factors in the activated sludge process, Mr. McKinney has isolated and studied several zooglea-producing organisms present in activated sludge. He has shown that purification is probably caused by the activity of several different organisms. In his theory on floc formation, he has again brought to attention the importance of the colloidal nature of sewage in biological treatment.

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Industrial Wastes

DESTRUCTIVE CATALYTIC OXIDATION OF AQUEOUS WASTE MATERIALS *

By Ralph V. Green and D. V. Moses †

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The Belle, W. Va., plant of the Du Pont Company is faced with the usual problem of keeping dilute solutions of organic wastes from entering the river. Since there appeared to be no conventional method of treatment for this type of waste material applicable to the Belle location, a study was instituted of other possible methods. From this program there was developed a catalytic oxidation method of treatment which destroys the oxygen-consuming properties of waste materials by oxidizing the organic content to harmless end products. This discussion is confined to the vapor phase treatment, which has been rather fully investigated. There is, however, experimental evidence that the catalytic liquid phase oxidation is also feasible. The present paper covers the laboratory scouting, semi-works-scale tests, the proposed full-scale installation and, briefly, some comparative economics of the vapor phase process.‡

Consideration of Other Processes

In consideration of how these dilute wastes could be processed, it was determined that they were not susceptible to recovery at a cost comparable to disposal and that the possibilities of recovery, recirculation, and re-use had been exhausted. Under this conclusion the following choices were apparent:

1. Biological treatment as used on sewage for by-product disposal was considered. Indications were that trickling filters would handle 1,000 lb. of B.O.D. per acre-foot per day. With the Belle load, such treatment would require more level land than could be made available close to Belle, which is situated between the hills and the Kanawha River. Also, the activated sludge process, with its auxiliaries, is space-consuming. Most serious, however, is the toxic nature of some of the chemicals to biological growths. Hence, these methods were not considered applicable.

2. Burning of the waste materials by exposure to air at temperatures at or above 760° C. was considered. This is an entirely feasible process and its choice or rejection depends entirely upon economic considerations, which are discussed later. An installation of this type is in operation for treatment of some of the Belle wastes; it was chosen because of the characteristics

* Presented at Fifth Annual Conference, West Virginia Sewage and Industrial Wastes Assn.; Charleston, W. Va.; Oct. 3–4, 1951.

† Deceased.

‡ The DuPont Company has patent applications pending on its developments in the waste disposal field. Upon the issuance of patents covering these developments, the company expects to place them upon the Register of the United States Patent Office as available for licensing on a reasonable royalty basis. For use in the waste disposal field it is expected that the royalty asked, if any, will be purely nominal.

of the wastes and the available equipment.

Since the work reported in this paper has been completed, a similar method for disposal of organic vapors has been reported in the literature (1). The process differs from that developed at the Belle plant in that it is applicable to low concentrations of hydrocarbon vapors in air, whereas the process described herein is applicable to aqueous waste materials containing low concentrations of a number of types of organic compounds.

Early Work

The early work on this process was started when a literature reference was found to the beneficial effect of low concentrations of cobalt on the rate of oxidation of sodium sulfite in solution. This suggested that the oxidation of organic material might be feasible. It was tried on methanol-water solutions, but little or no catalytic effect was found. Later it was found that more drastic conditions were required for the liquid phase oxidation. There was then set up, in the laboratory, a simple apparatus enabling passage of the vaporized waste with air or oxygen through a bed of zinc and manganese chromite catalyst. This worked at once and demonstrated that reductions in oxygen consumption of more than 99 per cent were obtainable.

Laboratory Work

The laboratory work served as a means of establishing the effect of important variables, exploring the effect on a wide variety of waste materials, and determining catalyst compositions which are active. Variables studied were: space velocity, operating temperature, and light-off temperature. Materials catalytically oxidized and with which substantial conversions were attainable, were as follows:

1. Prepared solutions containing methanol, formic acid, acetic acid, n-valeric acid, n-caproic acid, adipic acid, formaldehyde, acetone, cyclohexanone, benzene, or hexamethylene diamine.
2. Plant wastes containing formaldehyde, formic acid, methanol, methyl cellosolve, ethylene glycol, and 2, 3 butylene glycol.

Catalysts which have exhibited activity are those composed principally of the oxides of copper, chromium, manganese, nickel, and cobalt.

Laboratory Equipment

The laboratory equipment is shown in Figures 1 and 2. The essential features consisted of a ¾-in. i.d. stainless steel tube contained in an electrical resistance furnace. The tube was packed with catalyst as shown. The inlet vapors first passed over pyrex glass beads to ensure vaporization, then over 35 ml. of catalyst, in which two thermocouples were centrally located, and finally out through pyrex glass beads used as support or spacers. The wastes were vaporized in a similar furnace as shown, the approximate vaporizer temperature being measured by a shielded thermometer. Figure 1 shows the assembled apparatus. The waste and the air were drawn through the catalyst tube or converter by a vacuum pump, the vacuum on the system usually running less than 10 in. of water. The converter off-gases passed through a water-cooled condenser into a collecting bottle. After measurement in a wet test meter the off-gases were discharged from the system by the air blower.

Temperatures were measured by the use of chromel-alumel thermocouples and a portable potentiometer.

Experimental Procedure

In starting out a run, the catalyst was first heated to above 400° C. with air flow, but no feed, in order to "season" the catalyst and remove the

graphite used in pilling. This procedure was considered necessary to remove any high initial activity and to avoid any effects which the graphite might have. Results obtained after this "seasoning" treatment were termed initial results. The feed and air were both kept on during the period of heating, but the feed was turned off during cooling of the catalyst.

The temperature at which the reaction started, or light-off temperature, was determined by bubbling the off-

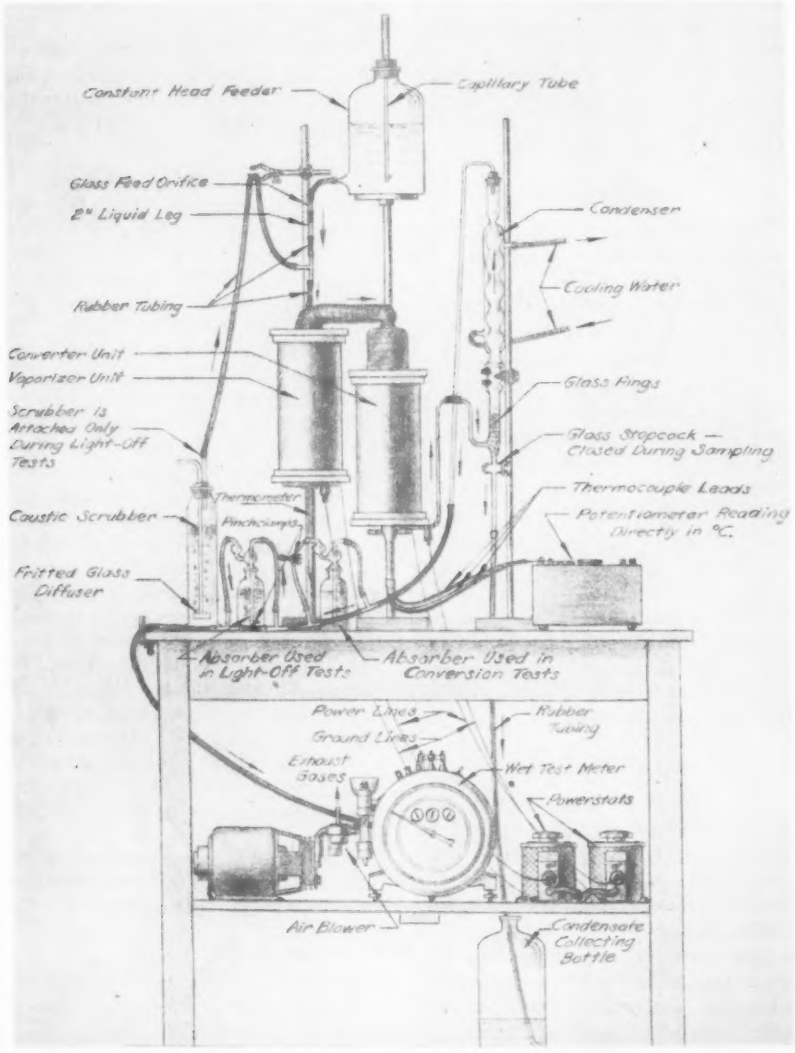

FIGURE 1.—Laboratory-scale catalytic waste oxidizer.

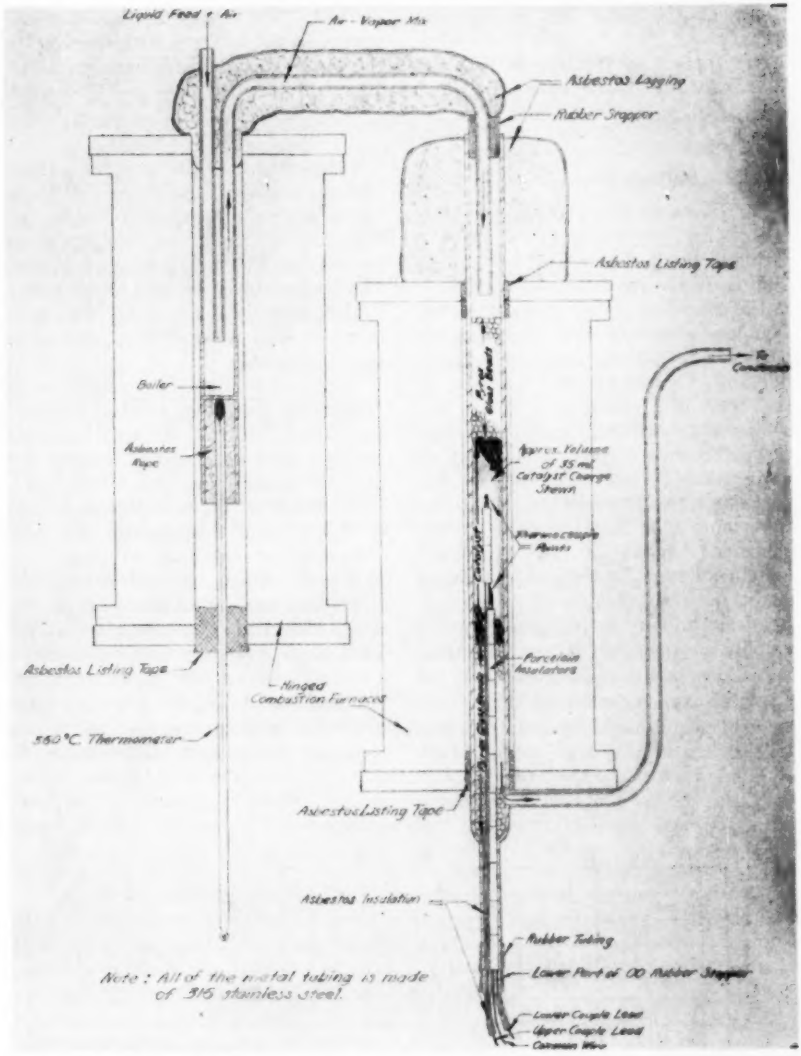

FIGURE 2.—Details of vaporizer and converter of laboratory-scale catalytic waste oxidizer.

gases through a solution of $Ba(OH)_2$ and observing the point at which the solution began to cloud. The CO_2 in the incoming air to the system was removed by bubbling it through a caustic scrubbing solution, using a fritted glass diffuser. This scrubbing was begun several minutes before starting the test, in order to flush out the system completely. The catalyst temperature was increased slowly during the test to avoid overshooting the light-off as a

result of the time lag through the system.

Air rates were equivalent to about 10 cu. ft. per pound of waste, which was equal to a 300 to 700 per cent excess.

Conversion Determinations

Samples for conversion tests were taken by scrubbing the off-gases through about 200 ml. of water and adding it to the condensate collected in the condenser. The per cent conversion was generally determined on the basis of chemical oxygen consumed reduction. This was done by making up the combined absorber solution and condensate to 250 ml., and determining the dichromate oxygen demand of an appropriate aliquot. Per cent conversion was then obtained by comparing this value with the chemical oxygen consumed value of an equivalent amount of feed. In the case of straight chain monobasic acids (for example, n-valeric and n-caproic acids), which exhibit no chemical oxygen consumed value in the standard method for chemical oxygen consumed, the conversion was determined by B.O.D. reduction using the standard 5-day B.O.D. method. The decrease in chemical oxygen consumed was also checked by the B.O.D. method and by carbon balances.

Effect of Temperature

Temperature is the most important variable observed. As shown in Figure 3, any degree of treatment can be obtained with any of the catalysts tried by varying the catalyst temperature. The temperature required for complete oxidation depends upon the particular catalyst used. Above 700° C. a catalyst is not required.

Exposure to high temperature has a deleterious effect upon catalyst activity. In general, the procedure used to evaluate this effect consisted of heating the catalyst successively to 400°, 600°, 750°, and 900° C., with measurements of the light-off temperature and conversion after exposure to each temperature. Results for a few tests are given in Figure 4 to demonstrate the effect. Thus, a copper chromite catalyst after heating to only 625° C. required a temperature of 240° C. to obtain 90 per cent conversion, but after exposure to 910° C. a temperature of 285° C. is required for 90 per cent conversion.

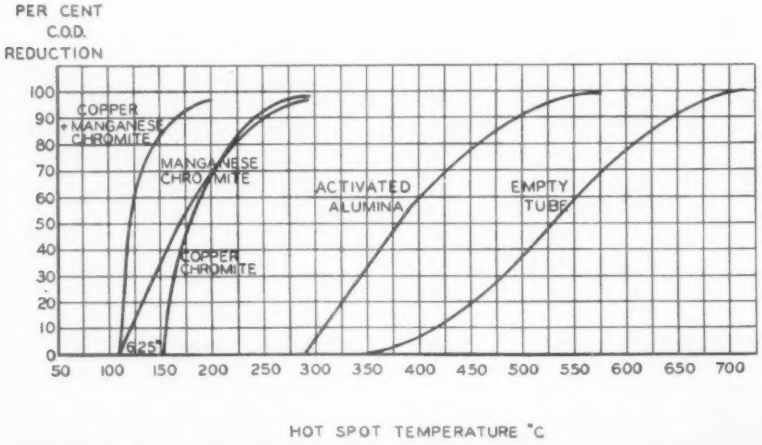

FIGURE 3.—Effect of temperature on conversion of feed from waste column heads.

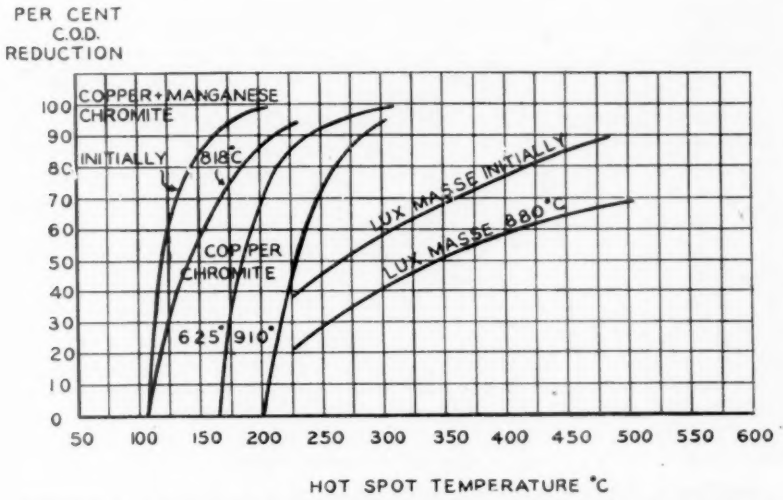

FIGURE 4.—Effect of high-temperature exposure on conversion of feed from waste column heads.

In addition to impairment of activity, overheating changed the physical form of the catalyst in a number of cases, causing shrinkage, breakage, or powdering.

In the case of oxidation reactions, the heat of reaction is so high that the temperature rise of the reactants may be in the order of several hundred degrees centigrade. Thus, provisions must be made to control the temperature to obtain good and constant performance.

As an example, if a water vapor containing 5 per cent methanol by weight is at its boiling point of about 100° C. and it is oxidized with 100 per cent excess air, which is also at 100° C., the resulting mixture of steam, CO_2, N_2, and oxygen will be at a temperature of 475° C. if there are no heat losses. Thus, for each per cent of methanol in steam the temperature rise on oxidation is about 75° C.

Space Velocity

Space velocity as used was calculated as the cubic feet of vapor, at standard temperature and pressure, divided by the cubic feet of catalyst. Relative to space velocity studies, Figure 5 indicates that the allowable space velocity for clean-up or high conversions is dependent upon the type of catalyst used and the temperature at which it is operated. For instance, manganese chromite will permit the use of much higher space velocities when oxidizing a mixture of formaldehyde, methanol, and formic acid. In general, the conversion decreases with increasing space velocity if the catalyst temperature is maintained constant.

Catalyst Activity and Life

The activity of a catalyst is considered to be determined by the degree of conversion which can be obtained at lower temperatures. A highly active catalyst, or one which lights-off and gives good conversions at low temperatures, is desirable, as such a catalyst in a plant unit would require a small amount of preheat or heat exchange surface.

A long life for the catalyst is also

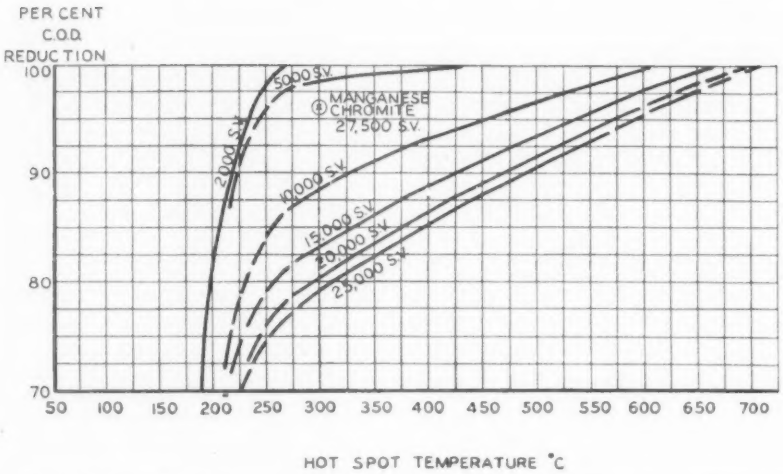

FIGURE 5.—Effect of space velocity on conversion of synthetic feed containing 1.5 per cent formaldehyde, 0.5 per cent formic acid, and 0.5 per cent methanol (catalyst, copper chromite).

essential for an economic process. Tests have been made in the semi-works, which demonstrate that under proper conditions of temperature and space velocity essentially complete conversion can be maintained for at least 1,000 hr. Actually, in the life tests made, 100 per cent conversion was still being achieved after 1,000 hr. of operation.

Relative to the physical forms of the catalysts which appeared to be preferred, it was found that the pilled catalysts exhibited more activity than the fused catalysts.

Catalyst Poisons

Limited tests have also been made to determine the effect of sulfur compounds upon catalyst activity and life. Sulfur is particularly bad at temperatures in the range of 200 to 250° C., but at 300° C. or above, small concentrations can be tolerated with a copper chromite catalyst. Again, the allowable concentration is dependent upon the type of catalyst.

Semi-Works

At the same time the laboratory work was being conducted, a semi-works unit was constructed and placed in operation. Because the wastes to be treated existed in the plant in a vapor state, it was decided to set up the equipment so that a portion of the plant waste streams could be processed through the catalytic oxidation unit. As finally developed, this equipment consisted of that shown in Figures 6 and 7. The waste streams to be treated are vapors from distillation columns and hence were drawn through the semi-works equipment along with the air for oxidation by a steam-vacuum jet. Oxygen-consuming materials in the vapors, which are normally condensed and sewered, consist of methanol, formic acid, formaldehyde, methyl cellosolve, and derivatives of ethylene glycol. The converter contained 0.5 cu. ft. of catalyst and was operated at waste rates of 200 lb. per hour and on air rates of 600 cu. ft. per hour.

Initially, tests were conducted using

only one of the streams. It was soon found that, because of fluctuations in the organic content of the waste, temperatures in the catalyst bed rose high enough to adversely affect the catalyst activity and life. Consequently, it was necessary to install automatic equipment for proportioning exhaust steam into the unit to dilute the organic concentration sufficiently so that the temperature rise due to oxidation was not excessive. It was then realized that for a plant installation to be successful some positive means would have to be provided to avoid runaway reaction; also that such runaway reactions represented abnormal organic losses from the process and should not be tolerated for economic reasons. Hence, the erratic performance of the oxidation unit led to improved plant performance with respect to yield. This finding also stressed the necessity of providing in a plant unit facilities to take care of emergencies when abnormal operation of the main plant units would be encountered.

The work at this stage of development indicated that a catalytic oxidation unit could possibly be used as a means of analyzing dilute aqueous wastes containing organic compounds. Thus, in such an analytical unit, a small portion of the waste could be passed through a small oxidation unit and the CO_2 liberated could be used as a measure of the organic content. The temperature rise could also be used as a measure of the organic content, and some constant steam bleed used to hold the temperature rise to within acceptable limits. Such an analyzer is being developed.

Steam was chosen as the diluent in the semi-works, rather than air, because of its greater heat capacity.

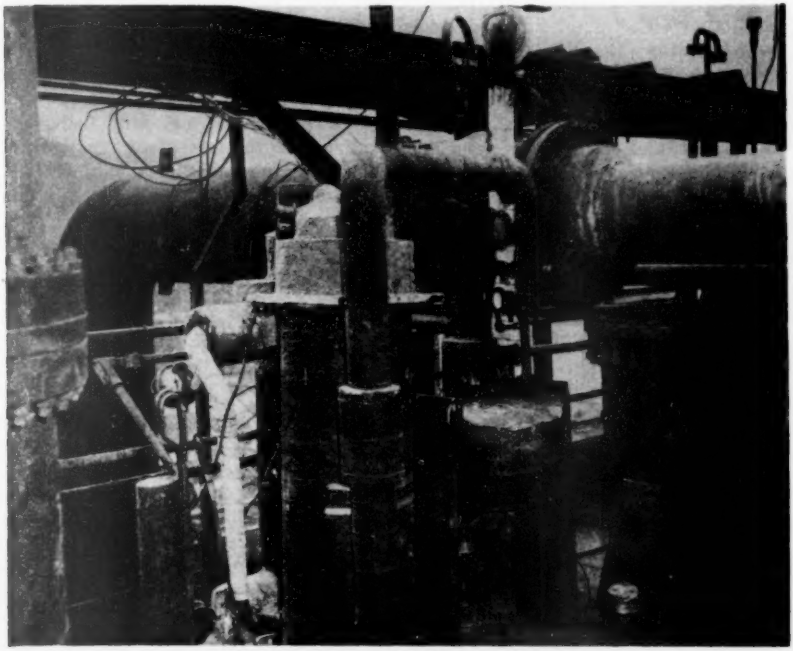

FIGURE 6.—Semi-works catalytic oxidation unit.

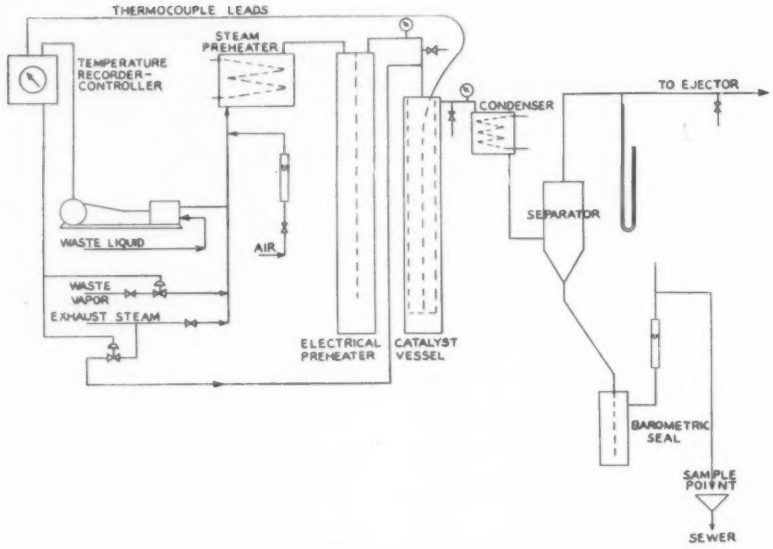

FIGURE 7.—Schematic diagram of semi-works catalytic oxidation unit.

Another effect noted in semi-works tests was that the light-off temperature of the catalyst increased with age. Consequently, it was necessary to install facilities to permit raising of the converter inlet temperature as required by the catalyst. As indicated later, direct gas firing can be used to bring the catalyst to reaction temperature. The preheater afforded conditions whereby conversions could be maintained and satisfactory catalyst life was realized. With a copper chromite catalyst, which is poisoned by sulfur, it was also substantiated through laboratory tests that the higher temperature made the catalyst more tolerant toward poisons.

With facilities to maintain the inlet converter temperatures up to 300° C. and with automatic equipment to dilute the waste stream with steam sufficiently to avoid excessive temperatures (above 600° C.), satisfactory performance with copper chromite was demonstrated when processing two wastes which contained approximately 3.5 and 8 per cent organics, respectively. Both of these streams were processed separately over copper chromite for periods of 1,000 hr., at the end of which complete conversion was still being obtained. In the new plant unit both of these streams will be combined and processed in one catalytic oxidation unit.

Plant-Scale Unit

In the manufacture of Belle products, sources of pollution arise from process waters that must be purged from the system. In removing these water streams from the process, oxygen-consuming materials are carried out also. One of the streams on which the major portion of the development work was done exists as vapor from a distillation column. It consists of 96.5 per cent water with 3.5 per cent organics, which are mainly methanol, formic acid, and formaldehyde, the formaldehyde predominating. Another stream, which also exists as vapor from a distillation column, consists of about 92 per cent water and 8 per cent or-

ganics. The organics in this latter stream are ethylene glycol derivatives. To abate the pollution, steps have been taken to install catalytic oxidation equipment.

Figure 8 is a schematic diagram of the new plant equipment. Because one of the columns operates under a vacuum, the distillate will be condensed and then pumped back up to the operating pressure of the oxidation unit and vaporized. This system promises to be less costly than the use of a blower. The other stream exists at a sufficiently high pressure so it can be forced through the oxidation equipment. The air will be introduced by a blower as shown. An existing electrical preheater will be used for start-up of the operation, but during operation the preheat will be supplied by heat exchange between the hot exit gases and the incoming vapors and air. Direct gas preheat would also be satisfactory. In the heat exchanger the organic wastes and air will be preheated separately to avoid any possible flashback or combustion in the heat exchanger. The air and vapors will then be passed over the catalyst and out through the heat exchanger to the atmosphere. For this pollution problem the converter volume has been calculated using a space velocity of 5,000. A copper chromite catalyst will be used. For dilution steam, 10-p.s.i. steam will be tied into the process ahead of the converter to provide means of avoiding runaway temperatures.

Economic Considerations

Other processes were considered for the disposal of the plant wastes in order to ensure the selection of the one most economically favorable. As the studies relative to the catalytic oxidation process indicated that complete conversion could be obtained above 700° C. without a catalyst, an oxidation process was evaluated on paper wherein the wastes would be burned with natural gas and air in a refractory-lined furnace. This "burning" process, which has been shown to have some economic advantages, was compared with the catalytic oxidation process. However, it was shown that at low concentrations of organic material in the wastes the catalytic oxidation process is more attractive. Furthermore, as yield losses are decreased and the concentration of organics in the wastes

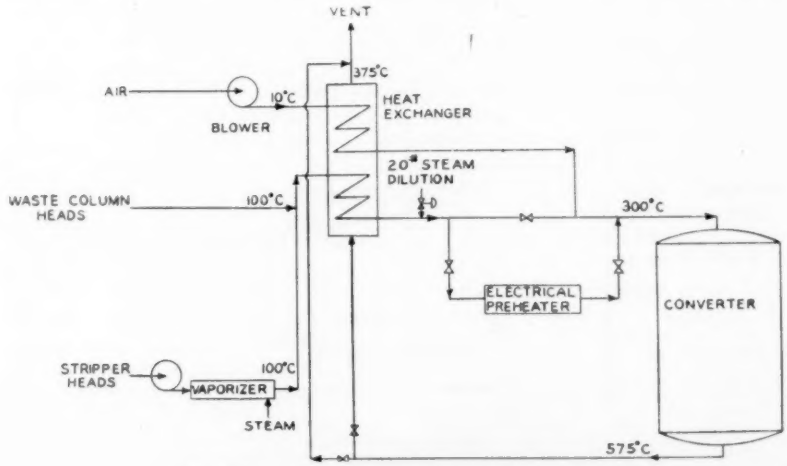

FIGURE 8.—Schematic diagram of plant-scale unit.

approaches zero, the catalytic oxidation process becomes more favorable.

Some of the interesting trends developed are shown in Figures 9, 10, and 11, for which the data were developed for a hypothetical case wherein 10,000 lb. per hour of a waste containing 5 per cent methanol is to be discarded. It must be realized that for each individual case the heat effects must be evaluated and a selection of the disposal process based upon the calculated results. As indicated by Figure 9, the quantity of natural gas required to burn the waste just mentioned in a refractory-lined furnace increases as the concentration of the organic in the waste stream decreases. At a level of 1 per cent organics the natural gas required is about 1.6 times the natural gas required at a level of 5 per cent organics in the waste. The resulting operating cost comparison may be as shown in Figure 10, which indicates that above 5 per cent organics in the waste, burning of the waste in a refractory-lined furnace may be preferable to catalytic oxidation. In de-

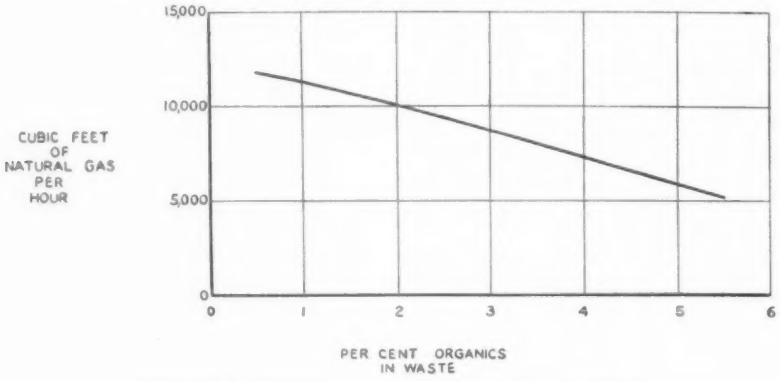

FIGURE 9.—Natural gas requirement for burning wastes.

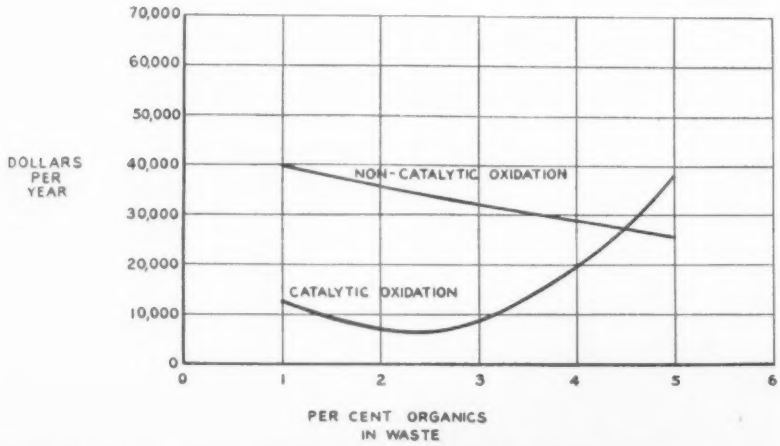

FIGURE 10.—Comparative operating costs for catalytic and non-catalytic oxidation.

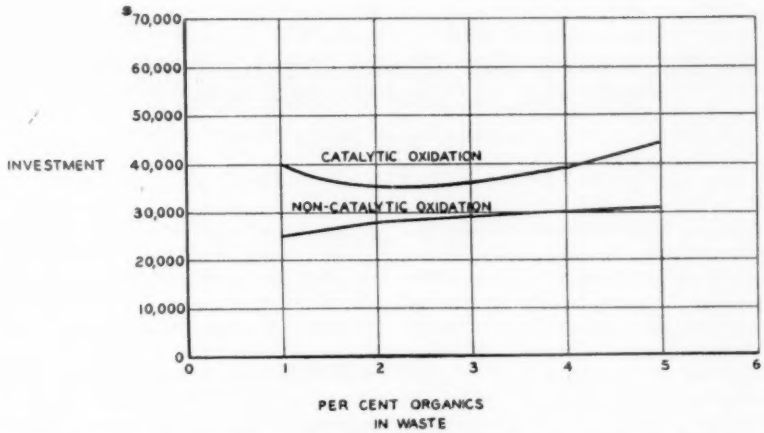

FIGURE 11.—Comparative investments for catalytic and non-catalytic oxidation.

veloping these costs, steam was chosen rather than air as a diluent to hold the catalyst temperature in the operating range because of its greater heat capacity. Because the dilution steam requirement increases as the organic content of the waste increases, costs for the catalytic oxidation process increase at the higher levels of organics. Because of this greater heat available at the higher level of organics, the burning process requires less natural gas and hence, operating costs are less.

In developing these costs, natural gas was valued at 35¢ per 1,000 cu. ft. and exhaust steam at 30¢ per 1,000 lb.

In most cases, investment costs for catalytic oxidation will be greater than those for burning. But as the level of organics in the waste decreases and approaches a level where the heat evolved is just sufficient to raise the reactants to the required catalyst temperature, a minimum investment is required for a catalytic oxidation unit. This is shown in Figure 11. Actual costs for each particular case must be independently developed. The economic data are shown to indicate the various ramifications of applying the process to actual cases.

Summary

Thus, it is believed that through the studies reported a very worthwhile process has been developed for disposal of dilute aqueous organic wastes. Operating conditions have been established and effective catalysts have been uncovered. The process compares favorably with other methods of waste disposal.

Acknowledgments

The research work reported in this paper includes the combined efforts of several persons. Joseph R. Clark conducted the laboratory-scale studies and Sheldon Gray carried out the major portion of the semi-works research. L. C. Peery, R. H. McKane, and C. L. Isbell also contributed to the development of the process.

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INSTRUMENTS AND THEIR APPLICATION IN THE CONTROL OF INDUSTRIAL WASTES *

By W. N. Greer

Leeds & Northrup Co., Philadelphia, Pa.

The use of instruments in industrial waste treatment can logically be considered in connection with a survey to determine methods of treatment and treatment plant design, as well as with automatic control of treatment and the recording of pertinent data in plant operation. Instruments are not available for all types of measurements involved; fortunately, however, they are available for those which are most critical in determining plant layout design. Proper selection of the instruments for survey work will also usually permit of their being used in the final plant operation.

Survey and Sampling

Numerous papers have been given on sampling methods, but in connection with those measurements which are critical in determining treating plant capacity (namely, flow rate and pH of raw waste) it should be emphasized that, where possible, these measurements on any survey should be made on a continuous basis. Average or composite sample measurements will give information relative to average demands, but only minute to minute variations in flow and acidity will give the information necessary to determine actual control requirements.

Flow measuring devices are familiar to those associated with the industrial waste treating field, and have been amply covered in various publications (1). The measurement of flow is perhaps of more value in a survey than it is in normal plant operation. Flow rates, when combined with the acidity of the raw waste, are factors in determining the proper retention and its distribution, and in determining the reagent treating requirements and, thus, in selecting and sizing the controlled feeding device. As all of these must be determined on maximum demands, and upon minute to minute variations in the raw waste, the value of continuous flow measurements in survey work can be appreciated. If the character of the wastes is such as to make it advantageous to separately treat acid wastes and alkaline wastes, it becomes advisable to determine the flow rates of both types of waste.

For measurements of pH in survey work, use can be made of a pH recorder, a controller, or a continuous pH indicator, any one of which might later serve in permanent plant operation. There are available recently developed a.c.-operated pH indicators, which can be quite satisfactorily used for continuous pH indications on raw industrial wastes when used with a suitable electrode system. One such recently developed indicator is shown in Figure 1. Covering the pH range 0 to 14, with temperature compensation from 0 to 100° C., either manual or automatic, and with a high degree of stability over long periods of time, it provides a satisfactory means for logging measurements at any desired time intervals.

With an electrode assembly which can be immersed in the raw wastes, and with leads run any required distance to the meter, the necessity of collecting samples is eliminated and a quite satisfactory arrangement for obtaining the

* Presented at 24th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; St. Paul, Minn.; Oct. 8–11, 1951.

required minute to minute variations in the raw wastes is provided. Such an electrode assembly installed in a cyclator is shown in Figure 2. For survey work, such an electrode can usually be installed in a sewer or other waste discharge line.

The previously mentioned a.c. pH indicator can also be used for electrometric titrations for total acidity or alkalinity concentrations, and such information, when coupled with the total flow, is, of course, necessary in determining total reagent treating requirements.

In those treatments involving the reduction, for example, of hexavalent chromium to trivalent chromium, this meter with suitable electrodes can be used in determining the optimum point in the treatment.

In normal plant operation the indicator serves a usable purpose in checking the performance of recording or control equipment and for spot checks at any point in the treating system.

Where it is desired to obtain continuous pH records, recording equipment is available. These can be single- or multiple-point recorders, the latter being convenient where it is necessary to obtain survey data in two or more waste lines, particularly if the points of measurement are widely separated. The detecting elements may be installed several hundred feet from the recording instrument. Proper selection of such recorders for survey work will permit of their later use in plant operation should the plant layout and record requirements be such that data from two or more points will be required.

Control

The factors governing the controllability of waste treatment to give an effluent within a specified pH range have been discussed in some detail elsewhere (2), but due to their importance are repeated here, as follows:

1. Flow rate.
2. Acidity.
3. Retention, and its distribution in the treating system.
4. Control point, or allowable pH range of treated waste.

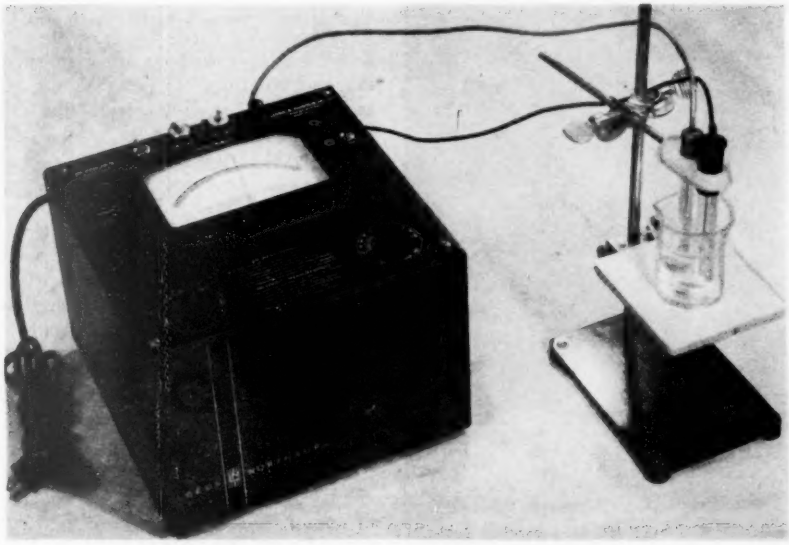

FIGURE 1.—Manual or automatic pH indicator of a.c.-operated type.

5. Agitation.
6. Rangeability of reagent feeding devices.
7. Detection lag.

Factors 1 and 2, with 4, permit the determining of points 3 and 6. Factor 5 is a "must" for two reasons: first because a uniform measurement is required if uniform control is to be obtained; and, second, it reduces point 7 to a minimum, which is essential in pH control. Raw waste flow rates and acidity are thus vital factors, which, if possible, should be measured continuously in any survey. They mean the difference between too small a treating plant with unsatisfactory control or an oversized plant with corresponding costs.

With given acidity and flow there is a minimum retention, properly distributed, which will give the required results. Almost without exception, satisfactory control cannot be obtained in a waste line as a treating system. Such a system has a minimum retention, inadequate mixing, and an excessive detection lag. In some cases, particularly those in which the acidities are high and change rapidly, it is advisable if possible to provide retention ahead of the treating system so that the fluctuating acidities are averaged out, or at least the rates of acidity changes are materially slowed down prior to their introduction into the treating system. In some other cases it is possible to widen the pH control band, where there is sufficient holding time after treatment but before the waste is diverted to a stream, to average out the controlled variations.

FIGURE 2.—Electrode assembly for pH measurement as installed in cyclator.

It hardly seems necessary, but experience has occasionally shown otherwise, that some judgment must be exercised in some minor details. For example, if over-and-under baffles are used to separate tanks in series, such baffles should be alternately over-and-under or *vice versa*, and not, for example, one under baffle immediately following another. This simply results in short circuiting of flow and loss of mixing capacity. Reagents should not be introduced in dead spots, or where they might be carried out of the reaction chamber without adequate mixing and reacting. If possible, the reagent should be discharged from the controlling device (valve) above the liquid level in the treating tank. It is often advantageous to be able to see the reagent flow. One of the problems involved in the control of waste treatment is that concerned with suitable feeding devices for lime slurry. On installations involving appreciable lime demands, there is no particular problem, as butterfly or patent valves may be used on relatively high lime slurry flows. For small treating systems requiring relatively low rates of lime feed, it usually becomes necessary to use a dilute slurry to obtain a sufficiently high flow rate to permit use of one of the above feeding devices, or to use very dilute lime and an open

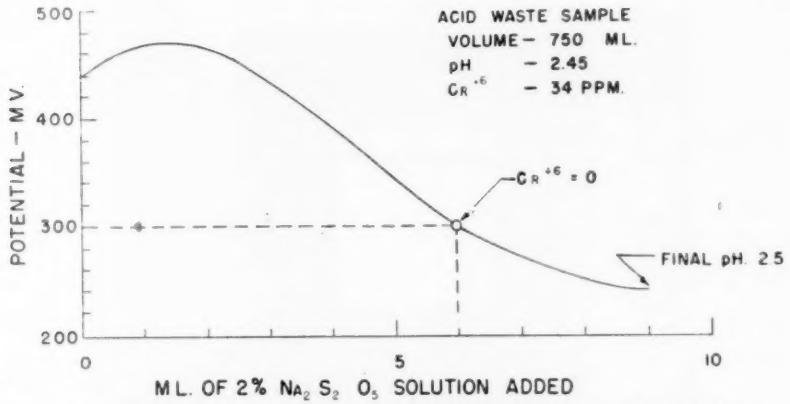

FIGURE 3.—Titration curve (3) for redox system using sodium metabisulfite.

type of valve which will not readily plug with suspended material.

Miscellaneous Measurements

Oxidation—Reduction

In the reduction of hexavalent chromium to trivalent chromium, the reaction is carried out in an acid medium, usually around pH 2. The end point or control point is measured by an oxidation-reduction electrode system, which is essentialy a pH system in which the glass electrode is replaced by a bright platinum electrode.

Such a treatment, using ferrous sulfate, has been described by Kelch and Graham (3); one using sodium metabisulfite has been described by Gard, Snavely, and Lemon (4). The titration curve established by the latter is shown in Figure 3.

The same considerations that apply to a satisfactory control arrangement of pH apply to oxidation-reduction control. The a.c. pH meter may be used to measure the redox potential in survey work, or for checking in regular plant operation. A redox controller is shown at the top in Figure 4. In this case the redox control is set at 380 millivolts; the instrument is essentially the same as the pH controller shown at the bottom of Figure 4. This pH controller is operating on the combined chromium reduced waste and the oxidized cyanide waste of a treating plant, controlling the additions of lime slurry to precipitate metal ions and to meet the pH requirements of treated effluent.

Electrolytic Conductivity

In some operations acid leakages occur at infrequent intervals and during normal periods of no leakage it is not desirable to divert the water to the waste treating system. Such an instance is exemplified by the coolers in sulfuric acid plants. If a leak does develop, the concentration of acid in the water is fairly high and it becomes necessary, of course, to send it through the treating system. It is possible to use electrolytic conductivity to measure the acidity of such waters. Because the conductivity changes greatly with any appreciable leakage, the measurement can be used to sound an alarm, or, if desirable, automatically start pumping or otherwise diverting contaminated water to the treating system whenever leakage develops.

In such cases, an abnormal demand of lime is called for, much beyond the capacity of the normal control system. Under such conditions, two valves are operated in sequence, the first handling normal treatment, with the second valve of the required larger capacity

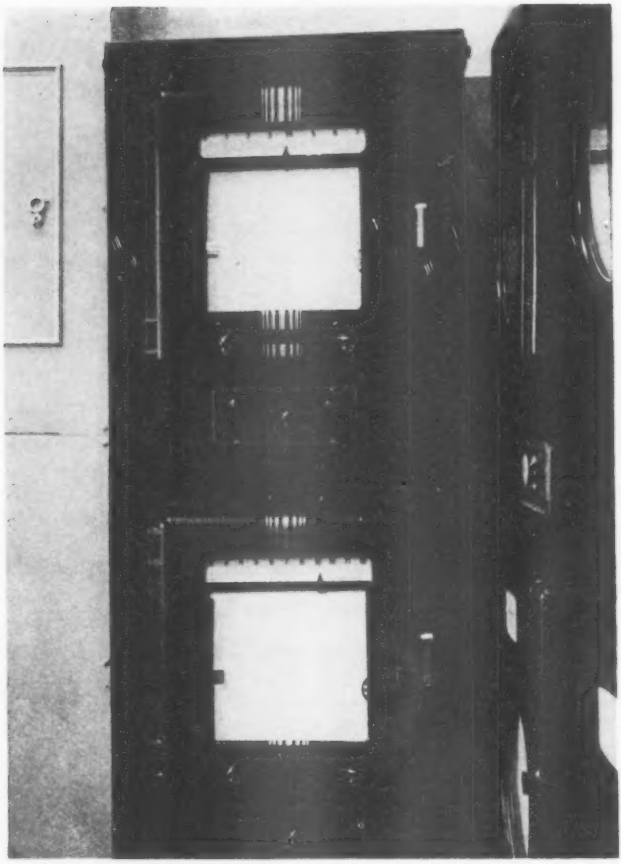

FIGURE 4.—Redox controller (above) and pH controller (below) in treatment plant for chromium and cyanide wastes.

going into operation when the normal treating valve has reached its maximum limit.

Summary

The importance is stressed of continuous measurements in survey work, particularly on raw waste flow rates and acidities, in determining treating plant layout in order to meet control requirements. Suggestions are made that proper selection of survey instruments will permit their use in the final plant operation. Requirements for control are briefly outlined and some specific measurement applications are described.

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DISCUSSION

By Isadore Nusbaum

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Few individuals would disagree with Mr. Greer's contentions concerning the value of a continuous record of the quality or quantity of waste discharges. Fortunately, many devices are available for indicating or producing a record of flow in open or closed systems. Unfortunately, too few instruments have been developed which are adaptable to the continuous control of industrial wastes. These are principally, as mentioned by Mr. Greer, the pH meter, used for either acidity and alkalinity or oxidation-reduction control depending upon the electrode system, and the conductivity meter. Some few instruments have been developed using a photo-electric cell as the sensitive element for recording color intensities or turbidity in industrial wastes.

Although the value of a continuous record is undisputed, there are definite limitations to the use of the instruments described above, and it may be more desirable, under some circumstances, to use the simpler non-continuous devices to obtain data on an intermittent basis. Statistical methods can probably be used to evolve a sort of quality control method for the wastes. However, such instruments and methods cannot readily determine sudden failures or losses in the disposal system which may cause considerable damage.

Oxidation-reduction and conductivity instruments are particularly susceptible to poisoning of the electrode systems. Adherent physical or chemical coatings may create an almost impervious barrier between an electrode and the wastes. Oil and grease, in particular, will render almost any active element of a recording or controlling system inoperative. Instances have been noted where exposure of a glass electrode to high pH solutions has apparently caused the adsorption of alkali ions at the glass interface, resulting in a lag in the responsiveness of the instrument.

Under some circumstances many instrumental difficulties can be avoided by the proper segregation of wastes. Plugging of sampling lines and surrounding of immersion electrodes by inactive barriers can be virtually eliminated. The location of the active element or sampling point is of prime importance. It has been noted (1) that obtaining a satisfactory sample in waste disposal was far more important and difficult than the means of analysis. This is equally true for instrumental methods wherein the sampling point is part of the analytical system.

The instrument manufacturers would be the first to admit that their instruments are anything but foolproof. Indeed, the elaborate instruction manuals accompanying the instruments are meant for thorough study. Careful maintenance and operation are necessary to produce continuing data and results. Nevertheless, the instruments provide a valuable tool for the operation of waste disposal systems and the safeguard of sewage treatment plants and receiving waters.

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ASSIMILATION OF DAIRY WASTES BY ACTIVATED SLUDGE

II. The Equation of Synthesis and Rate of Oxygen Utilization *

By Sam R. Hoover and Nandor Porges

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In previous investigations, the authors (3)(4) have studied the biochemical oxidation of milk solids by activated sludge. The primary reaction was shown to be

$$\text{Milk solids} + O_2 \rightarrow \text{bacterial cells} + CO_2 + H_2O. \quad (1)$$

The total cell tissue synthesized was found by analysis of the protein and carbohydrate contents of the cells to be equal to 47 per cent of the protein and carbohydrate in the milk solids (3). On a weight basis, the yield of cell material was slightly higher; about 52 per cent, for the cells contain about 9 per cent ash. These results were obtained in continuous flow experiments after steady-state operation had been attained. In a later study of this assimilation reaction, the oxygen consumed and carbon dioxide produced were measured manometrically (2). Simultaneous chemical analysis of the amount of substrate remaining was employed to determine when the substrate was exhausted. It was established that the substrate was completely consumed when about 32 to 40 per cent of the oxygen required for complete oxidation had been used. Conversely, an assimilation of 60 per cent was indicated by these data.

The respiratory quotient (R.Q.), which is the ratio of the volume of CO_2 produced to that of oxygen consumed, was determined. The R.Q. of a biochemical reaction is of value because it gives a direct measure of the conversion of atmospheric oxygen to carbon dioxide. If the substrate and non-volatile reaction products are known, the equation of the occurring reaction can be established. For example, the complete oxidation of ethyl alcohol to CO_2 and water has an R.Q. of 0.67, whereas the oxidation of the same compound to acetic acid requires oxygen and produces no CO_2; the R.Q. is, consequently, zero. For the assimilation of milk constituents by cells, the R.Q. was 1.00 for casein, 1.04 for lactose, and 1.03 for skim milk.

Composition of Cells

For a detailed consideration of the system, however, a chemical analysis of the synthesized cell tissue was required. The previous analyses of the cells had been for carbohydrate, protein, and ash content. The oxygen, carbon, hydrogen, nitrogen, and ash contents of the cells were determined, therefore, so that the empirical composition of the organisms could be established. As far as is known, these are the first direct determinations of oxygen in microorganisms. The percentage of each element present was calculated to a molar basis by dividing the determined value by the respective atomic weight. As shown in Table I, $C_5H_7NO_2$ is a close approximation of the resultant composition.

* Presented in part at the meeting of the American Assn. for Advancement of Science; Philadelphia, Pa.; Dec. 27, 1951.

Part I of this series appeared in This Journal. **23**, 2, 167 (Feb., 1951).

TABLE I.—Empirical Composition of Sludge Organisms

Constituent	Weight (%)	Atomic Ratio	
		%/At. Wt.	%/At. Wt.
C	47.26	3.94	4.89
H	5.69	5.65	7.02
N	11.27	0.805	(1.0)
O	27.0	1.69	2.09
Ash	8.61	—	—
Total	99.83	—	—

It is realized that a microbial cell is an organized system of almost infinite complexity; this empirical formula expresses only the statistical average proportions of the major atoms of the organic constituents. For purposes of calculation, this $C_5H_7NO_2$ unit has a "mole wt." of 113. Corrected for the ash content of 8.6 per cent the weight of a "mole" of cells is practically 124 atomic weight units. This figure will be of value in subsequent calculations.

Cell Synthesis from Lactose

The conversion of carbohydrate to cell tissue requires energy, which is obtained by oxidation of a portion of the carbohydrate. Because no by-products are produced in significant quantities by this aerobic oxidation, the energy-yielding step must be the complete oxidation of lactose to carbon dioxide and water.

$$C_{12}H_{22}O_{11}\cdot H_2O + 12\,O_2 \rightarrow 12\,CO_2 + 12\,H_2O \quad (2)$$

For convenience, the repeating unit $\begin{array}{l}|\\ HCOH,\\ |\end{array}$ which requires one molecule of oxygen for its oxidation, is used.

$$(CH_2O) + O_2 \rightarrow CO_2 + H_2O \quad (3)$$
$$R.Q. = 1/1 = 1.0$$

The minimum equation for the conversion of carbohydrate to cell tissue, if ammonia is used as the source of nitrogen, is:

$$5\,(CH_2O) + NH_3 \rightarrow C_5H_7NO_2 + 3\,H_2O \quad (4)$$

Eq. 4 is balanced without oxygen consumption or CO_2 evolution. According to the manometric data, about 37 per cent of the oxygen required for completely oxidizing the sugar was used during this assimilation. Therefore, there must be added to Eq. 4 the oxidation of three units of sugar, according to Eq. 3, to give

$$3\,O_2 + 8\,(CH_2O) + NH_3 \rightarrow C_5H_7NO_2 + 3\,CO_2 + 6\,H_2O \quad (5)$$
$$R.Q. = 3/3 = 1.0$$

Three-eighths, or 37.5 per cent, of the amount of oxygen required for complete oxidation is consumed. The experimental R.Q. of 1.04 agrees well with the theoretical value of 1.0. The data on yield of cells by weight are also consistent: 240 atomic weight units, 8 (CH_2O), are used up, and 124 units of cells are produced; $124/240 = 52$ per cent yield by weight. The experimental data show a yield by weight of slightly greater than 50 per cent. The latter data are for the assimilation of dry skim milk, however, and not for lactose alone.

Cell Synthesis from Casein

Similar equations have been established for the oxidation and assimilation of casein. The four elements tabulated were determined directly. Both sulfur and phosphorus occur in casein; about 0.8 per cent of each. This content, calculated to the molar basis used, would equal only 0.05 atom per mole and therefore can be neglected. The "mole" weight of $C_8H_{12}N_2O_3$ is 184. This value, obtained from Table II, will be referred to later.

The equation for complete oxidation of casein is readily established if an assignment of the nitrogen can be made. It is probable that nitrogen is not oxidized until all the carbon has been oxidized; therefore, Eq. 6 was

TABLE II.—Composition of Casein

Constituent	Weight (%)	Atomic Ratio	
		%/At. Wt.	%/At. Wt.
C	52.85	4.40	8.15
H	6.48	6.43	11.9
N	15.12	1.08	(2.0)
O	24.76	1.55	2.87
Total	99.21	—	—

written on the basis of ammonia release.

$$C_5H_{12}N_2O_3 + 8\ O_2 \rightarrow 8\ CO_2 + 2\ NH_3 + 3\ H_2O \quad (6)$$
$$R.Q. = 8/8 = 1.0$$

Thus, by comparing Eq. 6 with Eq. 2, it can be seen that complete oxidation of one carbon atom from either lactose or casein requires one O_2 and produces one CO_2.

The minimum equation for the assimilation of casein into cell tissue may be written:

$$C_5H_{12}N_2O_3 + 3\ O_2 \rightarrow C_5H_7NO_2 + NH_3 + 3\ CO_2 + H_2O \quad (7)$$
$$R.Q. = 3/3 = 1.0$$

Eq. 7 is not rigorous, for it is based on the assumption that one-half the nitrogen is assimilated and one-half released as free ammonia. There is qualitative evidence of ammonia release when cells are grown on casein alone. Ammonia is apparent in the gas phase, and the pH of the solution is increased, but the amount of ammonia produced has not been determined. The minimum equation (Eq. 7) has an R.Q. of 1.0, the same as that observed experimentally. The amount of oxygen required for the assimilation (compare Eqs. 6 and 7) is three-eighths that for complete oxidation. The almost exact equivalence of the amount of oxygen required and of the R.Q. for the assimilation of lactose and casein into cell tissue is explained by this series of equations.

Cell Synthesis from Skim Milk Solids

The assimilation equations (Eqs. 5 and 7), each of which produces one "mole" of cells, may be compared further. Eq. 5 requires 8 (CH_2O) units or 240 atomic weight units of sugar, whereas Eq. 7 requires 184 units of casein. The proportion of 240:184 is essentially that of the relative proportions of lactose to casein in skim milk, 51:37, and the two equations may be summed directly, as follows:

$$8\ (CH_2O) + 3\ O_2 + NH_3 \rightarrow C_5H_7NO_2 + 3\ CO_2 + 6\ H_2O \quad (5)$$
$$C_5H_{12}N_2O_3 + 3\ O_2 \rightarrow C_5H_7NO_2 + 3\ CO_2 + H_2O + NH_3 \quad (7)$$
$$8\ (CH_2O) + C_5H_{12}N_2O_3 + 6\ O_2 \rightarrow 2\ C_5H_7NO_2 + 6\ CO_2 + 7\ H_2O \quad (8)$$
$$R.Q. = 1.0$$

The summation equation requires six-sixteenths, or 37.5 per cent, of the oxygen needed for complete oxidation; the ammonia required for the carbohydrate assimilation is furnished by the protein. Thus, no pH change due to ammonia release would be expected. The pH does not change when skim milk is the substrate (3). The R.Q. of 1.0 for the assimilation is in excellent agreement with the experimental value of 1.03.

The amount of cell tissue produced from a given amount of skim milk, according to Eq. 8, is $\frac{2 \times 124}{240 + 184} = 58.5$ per cent. This value is slightly greater than the 52 per cent observed earlier (2)(3). The difference arises, apparently, from the failure of the continuous-flow experiments to effect the complete conversion of skim milk to cells, carbon dioxide, and water as required by Eq. 8 and observed in the manometric experiments. Thus, it is probable that in continuous-flow or fill-and-draw experiments the maximum amount of cell tissue obtainable experimentally will be 52 to 55 per cent. If conditions do not permit the most rapid growth, the yield of cell tissue will be lower, for the cells will con-

tinue to oxidize (at a lower rate) the sugar and protein essentially according to Eqs. 2 and 6, with an accompanying increase in the proportion of the substrate oxidized to CO_2 and H_2O.

Endogenous Respiration

The reactions expressed by Eqs. 1 to 8 are those of the synthetic reaction. The cells produced in this reaction have what is called an endogenous respiration; that is, an oxidation of their own tissue for energy. It is analogous to the basal metabolism in humans.

$$C_5H_7NO_2 + 5\ O_2 \rightarrow 5\ CO_2 + NH_3 + 2\ H_2O \quad (9)$$
$$\text{R.Q.} = 1.0\ ^*$$

* The low Q_{O_2} makes determination of R.Q. difficult, for a CO_2 production of 200 to 300 μL. is required for an accurate R.Q. determination. However, duplicate values of 0.95 were obtained in the most satisfactory experiment.

Eq. 9 has an R.Q. of 1.0, which can be determined manometrically by measuring the rate of oxygen consumption of the sludge without added substrate. A Q_{O_2}, or rate of oxygen consumption, of about 12 μL. per mg. per hr. was reported previously. The Q_{O_2} reported for Eq. 8 was 50 to 150, about 10 times the endogenous respiration (2).

Polarographic Determination of the Rate of Oxidation

Direct determination of dissolved oxygen by polarographic measurements may be used to determine (a) the relative rate of oxidation by the synthetic reaction to that of endogenous respiration, and (b) the effect of low concentration of oxygen on these two rates. Oxygen depletion rates of bacterial sludge for various concentrations of nutrient were measured by a modification of the method

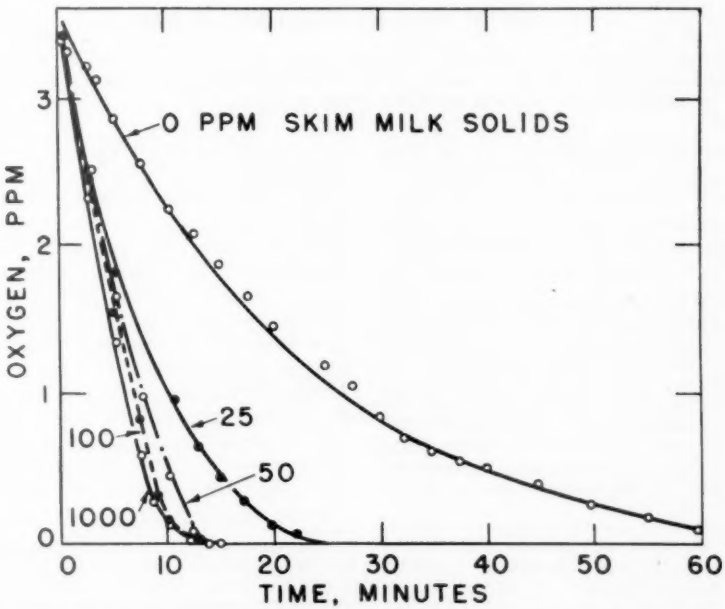

FIGURE 1.—Oxygen removed from solutions containing the indicated amounts of skim milk solids by activated sludge under anaerobic conditions.

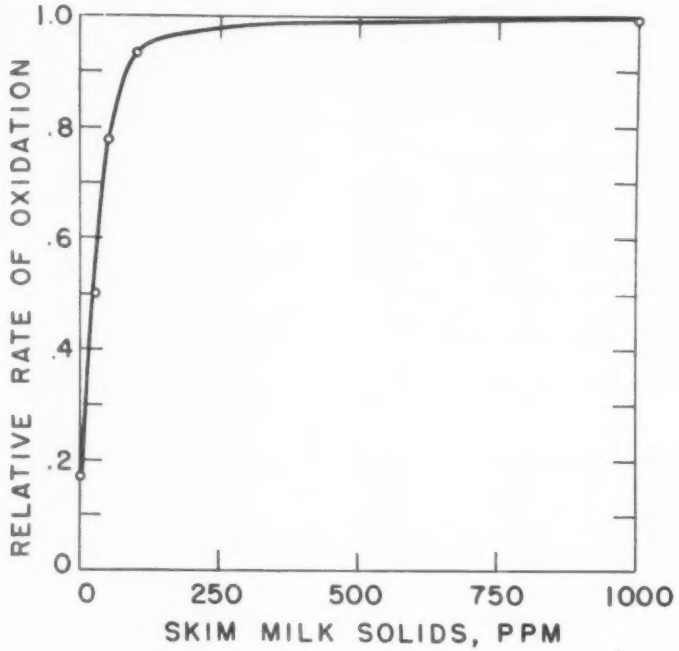

FIGURE 2.—Rate of oxidation by activated sludge as a function of the concentration of skim milk solids. The time required to reduce the concentration of oxygen to 0.5 p.p.m. for the maximum substrate concentration is taken as unity.

of Hixon and Gaden (1). In the present studies, oxygen depletion rates of active bacterial sludges were determined by recording continuous polarograms of the oxygen remaining in solution.† Measurements of oxygen depletion were made at 0, 25, 50, 100, and 1,000 p.p.m. of nutrient.

The results show a rapid and relatively constant rate of oxidation of skim milk solids. The curves of oxygen depletion (Figure 1) can be interpreted more satisfactorily when plotted as in Figures 2 and 3. The rate of oxidation as a function of substrate concentration is approximated by determining the time required to reduce the oxygen tension to 0.5 p.p.m. The most rapid rate of depletion at 1,000 p.p.m. is taken as unity. Any other arbitrary end point could have been selected without affecting the results signifi-

† Use of a sealed, modified Lingane H-cell (5) with nitrogen-filled head space prevented absorption of atmospheric oxygen by the sludge during the oxygen measurements. The oxygen remaining in solution was measured continuously at an applied potential of -0.5 volts *vs.* S.C.E., with the cell held at $25 \pm 0.1°$ C. The dissolved salts in the substrate served as the supporting electrolyte. The sludge was dispersed by high-speed agitation so that it would not settle rapidly before it was transferred to the H-cell. The sludge was aerated, and the nutrient was added and mixed by further air bubbling. After this, the air in the head space was replaced with nitrogen, the cell was sealed, and a continuous polarogram was recorded until the height of the oxygen wave attained a constant minimum value. These wave heights were calibrated with solutions containing known quantities of dissolved oxygen, and since the polarogram abscissae were expressed in minutes, oxygen depletion rate constants, p.p.m. O_2 per minute, were obtained directly from the slope of these waves.

cantly. The rate of assimilation by Eq. 8 is essentially constant above 100 p.p.m. of added skim milk. The time required to oxidize the waste, therefore, is directly proportional to the amount added in this range. It has been previously shown by Warburg respirometer studies that 1,000 p.p.m. are assimilated in about 6 hr.; 500 p.p.m. would then be assimilated in 3 hr., and other amounts in similar proportion. Such calculations assume that a sufficient amount of oxygen is supplied. In these experiments, the assimilation reaction proceeded at 6 times the rate of endogenous respiration shown by the control without added substrate.

Figure 3 shows the rate of oxidation of 100 p.p.m. skim milk solids (from Figure 1) as a function of oxygen concentration. Only below about 0.5 p.p.m. O_2 does the rate fall off appreciably because of lack of oxygen. The absolute rate of oxygen consumption is of practical importance; oxygen is removed from the solution at a rate of 0.35 p.p.m. per minute. The difficulty encountered in supplying oxygen at such a rate is one of the major problems in the aerobic treatment of dairy wastes.

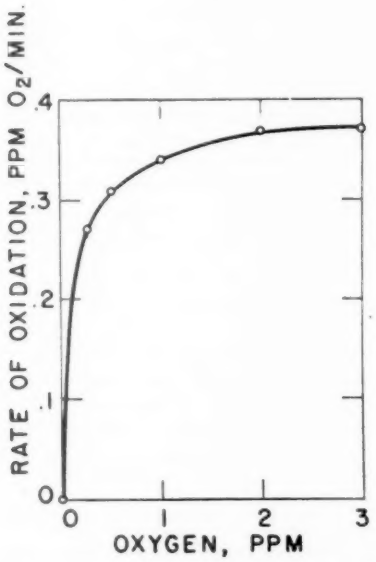

FIGURE 3.—Rate of oxidation of 100 p.p.m. skim milk solids as a function of oxygen concentration. The rate is taken from the slope of the curve for this concentration in Figure 1.

Discussion

Practical implications of the oxygen-depletion data are discussed above. Additional considerations, which are believed to be of importance in the design and operation of dairy waste disposal plants, may be derived from the equations established in this paper. The following calculations are based on 1 lb. of skim milk solids in 1,000 lb. of water; that is, 1,000 p.p.m.

Assimilation reaction (Eq. 8):	
O_2 required (%) for complete oxidation	37.5
Time required for assimilation (hr.)	6
Oxygen required for assimilation (lb.)	0.45
Rate of oxygen utilization (lb./hr.)	0.075
Endogenous respiration (Eq. 9):	
O_2 required (%) for complete oxidation	62.5
Time required for oxidizing 500 p.p.m. cells produced according to Eq. 8 (hr.)	30
Oxygen required for oxidizing cells (lb.)	0.75
Rate of oxygen utilization (lb./hr.)	0.025

The assimilation reaction is assumed to be 10 times as rapid as endogenous respiration. This relationship was obtained several times in a previous study. If the sludge were less active than is assumed, the assimilation reaction would be slower, perhaps requiring 8 hr. for completion. The rate of endogenous respiration is relatively constant, about 12 μL. per mg. per hr. (2), despite variations in the rate of substrate oxidation caused by changes in activity of the sludge. If about 2,500 p.p.m. sludge solids were carried in an aerator, the time for com-

pletion of the endogenous reaction would not differ appreciably, but the rate of oxygen utilization would increase proportionately (5-fold) and more oxygen must be supplied. In these experiments, the solids content of the sludge at the start was about 500 p.p.m.

Summary

Chemical equations for conversion of lactose, casein, and skim milk solids to activated sludge are established.

A similar equation is derived for the endogenous respiration of the sludge. The rate of these reactions is measured by polarographic determination of oxygen depletion. The various lines of evidence combine to give a quantitative description of the biochemical processes occurring in the oxidation of dairy waste by activated sludge.

Acknowledgment

The technical assistance of Janet B. Pepinsky and Lenore B. Jasewicz in determination of R.Q. values and of Mary Jane Welsh and Ruth Kelly in the elemental analyses on which the calculations are based is gratefully acknowledged. The authors are also grateful for the assistance of Constantine Ricciuti, who developed the necessary polarographic procedures for the continuous measurement of oxygen depletion of an oxygen-saturated activated sludge.

The study reported herein was made under the Research and Marketing Act of 1946.

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Stream Pollution

POLLUTION CONTROL THROUGH THE MECHANISM OF CLASSES AND STANDARDS *

By Anselmo F. Dappert

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In recent years there has been a trend toward adoption of classes and standards as an administrative mechanism for pollution control. Many states have incorporated in their laws either mandatory or permissive provisions for use of such a mechanism. Acceptance, however, has not been universal among the engineers and others responsible for administration of pollution control laws. Two schools of thought apparently have developed with reference to the matter: to classify or not to classify—that is the question. There are some who are much opposed to the idea of applying classes and standards to receiving waters. There are others, and it is suspected that they are in the majority, who believe that classification and establishment of standards for receiving waters is of considerable assistance in carrying on a sound program of pollution abatement and control.

Engineers who are opposed to the idea of classes and standards have expressed the opinion that engineering judgment should govern administrative decisions with respect to sewage or waste treatment requirements. No one could argue against this point of view. Certainly engineering judgment must enter into engineering decisions of all kinds. But the mechanism of classes and standards provides some assurance that sound engineering judgment will be applied in making decisions relative to treatment requirements. Furthermore, engineers who are opposed to classes and standards and who are involved with pollution control matters, whether they will admit it or not, must engage to some extent in the business of classifying and establishing standards for receiving waters. They may be unconscious of the fact that they are engaging in such practice, but they nevertheless do so. They may be prone to call it the exercise of engineering judgment.

Stream Usage Paramount

Who among designing engineers or among the engineers responsible for approving plans for pollution abatement works will base his decision as to the adequacy of proposed treatment works without some consideration of the uses made of the receiving waters and the effects the proposed effluent will have upon such waters? Works installed without reference to these matters are likely to represent either gross conditions of underdesign or overdesign. Whenever an engineer considers protection of a stream usage, he is thinking in terms of a stream class—although he may not go so far as to designate it by a letter or a number. Whenever an engineer becomes concerned with the effects an effluent

* Presented at 24th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; St. Paul, Minn.; Oct. 8–11, 1951.

may have on the dissolved oxygen or bacteriological content of a stream, he is thinking in terms of stream standards.

Some form of classification and adoption of stream standards is a fundamental necessity as a mechanism for pollution control. Without this mechanism, whether applied on a formal or official basis or practiced under the name of engineering judgment, pollution control cannot be adequate or effective, except as a happenstance.

Classification Defines Criteria

It is axiomatic that when engineers design or approve plans for pollution abatement works, they should apply sufficient sound engineering judgment to assure that the works will be adequate to meet the requirements of the particular receiving waters. "Half-baked" engineering judgment is not enough. The required sound engineering judgment, of course, can be developed without resorting to the use of any formal system of classifications and standards. But in respect to any particular pollution situation, sound engineering judgment is more apt to be developed if the engineer is guided by a carefully prepared and sound classification-standards system. Use of such system will assure to some extent the consideration of all factors that should be taken into account with respect to any particular problem.

The author recently reviewed with much interest the report of the Ohio Department of Health on the Water Pollution Study of Miami River. The Ohio law apparently does not require any formal classifications of or assignment of quality standards to the various waters of that state. But it does require some treatment for all sewage and waste discharges in accordance with plans to be submitted to and approved by the Ohio Department of Health. In the report to which reference is made there appear such statements as the following: "These Miami River studies have accomplished an evaluation of the pollution loads entering the river and its tributaries together with a determination of the effects of such pollution upon the receiving waters, all of which have made it possible in turn to determine the degrees of treatment of sewage and industrial wastes that will have to be practiced to maintain the receiving waters in a reasonably clean condition, with particular regard to low flow periods likely to be encountered." Although not labeled as such, this statement seems to be talking about classifications and standards of water quality.

Same Idea—Different Name

Also, in the foreword of the same report is the following statement: "Pollution was evaluated for the entire drainage basin; its effect under known hydrological conditions was observed, and the degrees of pollution reduction necessary to meet stream water quality objectives consistent with water usage were determined." Again, although not labeled as such, this statement seems to be dealing with stream classifications and standards.

In this report, also, some detailed discussion of water quality objectives is given, accompanied by this statement: "The general objective or desired result of regulatory measures is to restore and preserve the main stream and its tributaries for uses consistent with public health and welfare requirements, giving due consideration to the social and economic progress within the communities."

A few passages have been quoted from the report only to show that in Ohio the State Health Department appears to be engaged in one way or another with the problem of classifying streams and assigning quality standards to them, although the procedures in this respect are not definitely defined or formalized. In Ohio, apparently, what in New York are called "standards" are referred to as "water qual-

ity objectives." And, instead of having definite classes to fit any particular conditions of stream usage, as is done in New York, the Ohio Health Department considers each stream on its own merits and in relation to the particular existing or future possible uses made of the specific waters. This is, in effect, following a classification procedure, although not labeled as such.

Whether or not water pollution control agencies follow any systematized formalized procedures for classifying streams and assigning standards of quality to them is immaterial, although it is believed that the advantages weigh in favor of a formalized system. The point is that some form of classifications and standards, whether formalized or not, is essential to the administration of pollution control laws.

Fundamental Principles

It is important, of course, that any classification-standards system be a sound one. If it is to be used as a guide to engineering judgment and if it is defective, then there will be a tendency for these defects to enter into and influence engineering judgment. In respect to developing a sound classification-standards system, there are certain fundamental principles which should be recognized and incorporated in the system, as follows:

1. The system should provide for classifications based upon the best usage of waters in the public interest. Consideration of best usage should be the factor governing the assignment of any particular waters to a specified class. Best usage of waters in the public interest can be determined by taking into account all of the existing usages which are made of the designated waters and to some extent by taking into consideration any other usages which might reasonably be expected to be made of the waters in the foreseeable future. If the stream usages are known, then by taking into account several other factors, such as adjoining land usages, property valuations, industrial economy, public benefits from use of the waters, etc., a fair appraisal can be made as to which of the several uses are paramount so far as the public interest is concerned.

For example, consider a small stream that serves as a source of water supply for a small community and also as an outlet for the disposal of wastes from this community. Consider also, that this stream serves the general purposes of drainage, fishing, and recreation. The paramount use of the upper part of this stream could readily be determined as being for public water supply with drainage, fishing, and recreation as other subordinate usages.

The section of the stream above the water intake could appropriately be classed for water supply usage and so designated, either by name, number, or letter. Considering the lower section of this stream below the sewer outlet, some decision would need to be made as to whether recreational usage, or fishing, or disposal of wastes constitutes the paramount usage in the public interest. A decision might readily be made that fishing and disposal of wastes constitute the paramount best usages with recreational usage relegated to a position of unimportance. In such case, the lower section of this stream could appropriately be classified for fishing.

In this example, that part of the stream classified for water supply usage, if maintained in a condition suitable for this usage, would also be satisfactory for the other usages, such as bathing and fishing. Likewise, the lower section of this stream, if maintained in a condition suitable for fishing, would be satisfactory for any other usages except, possibly, water supply and bathing.

In certain cases, along highly industrialized streams it might readily be demonstrated to be in the best public

interest to classify the stream or portions thereof for industrial wastes disposal, because of the very great contribution which the industries make to the economy of the residents of the watershed, thus tolerating a considerable degree of pollution in the stream, but not to the point of becoming a public nuisance.

The classification system should be such that once a determination is made as to the best usage of particular waters, such determination will automatically designate the particular class to which such waters should be assigned.

2. The system should provide a sufficient number of classes so as to properly fit any conditions of water use which may be encountered. There are many recognized uses of natural waters. Most waters are used legitimately for several different purposes. However, most waters are not used for all possible purposes. Thus, in making best usage determinations, there will be considerable variation from stream to stream. Theoretically, the number of different possible best usage determinations for natural waters could run into the millions. Practically, they can be reduced to a very few in number by expressing the best usage determinations in terms of a single or paramount usage and using general language to include any or all other subordinate uses. Through the use of this procedure it is possible to develop a system having a few specified classes and to assure that there will be a proper class to which any waters may be properly assigned on the basis of any one of a million or more best usage determinations.

3. Each class should be defined in terms of a single best usage among any combination of uses, which calls for the most rigid or highest level of water quality for the protection of these various uses. Also, each class should define, when necessary, the conditions applying to such usage.

For example, in New York State two of seven classes for fresh surface waters have been defined as follows:

Class A

Best usage of waters: Source of water supply for drinking, culinary or food processing purposes, and any other usages.

Conditions related to best usage: The waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration, and disinfection, with additional treatment if necessary to reduce naturally present impurities, meet or will meet U. S. Public Health Service Drinking Water Standards and are or will be considered safe and satisfactory for drinking water purposes.

Class B

Best usage of waters: Bathing and any other usages except as source of water supply for drinking, culinary or food processing purposes.

In the New York State system there has also been established Class AA, applying to waters to be used for public water supply with only effective disinfection treatment; Class C for waters recognized for fishing, but not for bathing or water supply; Class D for agricultural or industrial water supply, but not for fishing, bathing, or drinking water supply; Class E for transportation and wastes disposal, but not for any other higher uses; and Class F for sewage and waste disposal.

With these seven classes it is felt that there is a class to properly fit any possible situation.

4. A set of water quality standards should be developed for each class. These standards should be established so that if and when met, the quality of the receiving waters will be satisfactory for the best usage as specified in the class definition. For example, for New York State Class B waters, the standards prohibit floating solids, settleable solids, and sludge deposits,

which are readily visible and attributable to sewage, industrial wastes, or other wastes, or which deleteriously increase the amounts of these constituents in receiving waters after opportunity for reasonable dilution and mixture with the wastes discharged thereto; they require the absence of ineffectively disinfected sewage or waste effluents; they establish a pH range between 6.5 and 8.5; if the waters are designated as trout waters the standards require not less than 5.0 p.p.m. of dissolved oxygen in the receiving waters, otherwise not less than 4.0 p.p.m.; they prohibit toxic wastes, oil, deleterious substances, colored or other wastes, or heated liquids in sufficient amounts as to be injurious to fish life or impair the waters for any other uses contemplated for Class B waters.

Any waters which meet the Class B standards certainly will be satisfactory for bathing, fishing, agriculture, or industrial water supply, and probably also for water supply after proper treatment, although Class B rules out water supply as a recognized usage.

5. Standards should be established applicable only to the receiving waters after reasonable opportunity for mixture and dilution of the waste effluents. Some allowance must be made for slight deterioration of water quality in the immediate vicinity of waste outlets. Standards should not be set for effluents except in each individual instance when it comes to designing or approving plans for remedial works. Nevertheless, in such instances the standards established for any particular effluent should be such as to assure, with a reasonable factor of safety, that stream conditions will be maintained so as to be in compliance with the stream standards.

6. Standards should be expressed in quantitative terms only when there is valid justification for establishment of quantitative limits. Otherwise, standards should be expressed in general language to indicate the conditions that must prevail in the stream if there is to be adequate protection for the best usage as defined for a particular class. For example, in New York State it was not felt that there was justification for setting any quantitative bacteriological limits for Class B waters, but it was felt to be thoroughly justifiable to specify definite quantitative limits for dissolved oxygen.

7. The standards should provide for requiring additional treatment when wastes discharged into one class of waters deleteriously affect or impair the water uses in a higher class of waters. In the New York system there is a supplemental standard applying to all classes to handle this problem.

The foregoing represents the writer's opinions as to the essential elements and principles which should be incorporated in any waters classification-standards system. The details naturally need to vary from state to state because of variations in the condition of natural waters from state to state. It is not thought possible to develop a uniform system which would be properly applicable to the conditions in each state.

Definite Objectives

Getting back to the question of whether or not to classify, there are some other considerations which lend support to the use of a classification system as a mechanism for pollution control.

From the standpoint of the designing engineer, knowledge in advance of what the stream requirements are gives him a concrete basis for design which should take out to some extent the guesswork involved in his consideration of specific problems.

From the standpoint of industry, at least in New York State, the adoption of classes and standards gives industry a firmer basis for studying and planning needed waste treatment facilities. In New York State, from the begin-

ning of the draft of legislation later enacted as a comprehensive water pollution control law, industry insisted upon classes and standards as a basic feature of the law. It is doubtful that the law could have been passed without the incorporation of this feature. Thereby it is believed that classes and standards have some very great public relations and educational benefits.

From the standpoint of pollution control agencies, the adoption of classes and standards establishes the necessity for certain procedures, which, although admittedly time consuming, are none the less progressive and constructive and in the long run will probably be very productive of good results. Situations must now be examined with a thoroughness that heretofore was not required. As a result, future solution of problems should be on a sounder basis than in the past.

Great benefits come from public discussions before waters are formally classified and assigned quality standards. Such discussions accomplish a great deal in the way of creating public sentiment favorable to progress. If classification of waters served no useful purpose other than informational and educational it still would be a well-justified procedure.

Problems of Application

It should not be thought that there are no headaches attached to application of a formalized system of classes and standards. Any "gimmick" undoubtedly has its drawbacks. Experience has shown that among lay persons there is considerable difficulty in understanding exactly what the classes and standards mean.

In the public mind there is a great deal of difference between Class A and Class D, for example, when as a matter of fact, so far as degrees of treatment called for are concerned there actually is not much difference.

In the New York State system the specifications in relation to floating solids, settleable solids, and sludge deposits are the same for Classes A, B, C, and D. For Class A disinfection of sewage effluents is required, whereas for Class D it is not expected unless the discharges impair the usages in waters of a higher class to which the Class D waters are tributary. For Class A there are standards covering phenolic compounds and odor-producing substances; these are omitted from the Class D standards. For Class D a drop to 3.0 p.p.m. dissolved oxygen is permitted, as is also a slight broadening of the pH range. The specifications relating to toxic substances are the same for Classes AA, A, B, and C, and are essentially the same for Class D. Thus, in most situations, whether waters are classified as A, B, C, or D the basic degrees of treatment called for are about the same. Admittedly this may be difficult for lay persons to understand and is a matter that requires considerable explaining. But in the public explanations and discussions of these matters are to be found the facts which make the advantages of a formalized system of classes and standards very much outweigh the disadvantages. From an administrator's viewpoint it might be less work to make decisions on an informal and unpublicized basis, but from the standpoint of engendering public interest and support in pollution abatement programs a formalized system has much to be said in its favor.

Much of the criticism that has been heard in regard to the issue of classes and standards is based, probably, on loose thinking. As an example, reference is made to the following quotation appearing in the June, 1951, issue of *Industry and Power:*

"At best, stream classification is only a stopgap. At its worst it is a form of discrimination, because it tells one group what it can or cannot do as compared to another group over the hill. It also works a hardship on a new industry, because lack of space on one stream may force the plant to

locate where pollution abatement is tougher. Result is migration of new plants to areas having more freedom. . . . In like manner, discrimination enters the picture when the diluting ability of a stream is allowed to affect permissible waste discharge."

Carried to its logical conclusion it must be assumed that the author of that statement believes that either (1) no industrial wastes should be treated or (2) all industrial wastes should be treated to a condition, say, that fish could thrive in the effluents prior to their discharge to the receiving waters.

In conclusion, there is still the question of whether or not to classify streams. The author's study and analysis of the matter puts him in the category of those who must vote a distinct "Yes."

DISCUSSION

By E. Sherman Chase

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Few sanitary engineers will quarrel with Mr. Dappert's advocacy of stream classification as an administrative method in pollution control measures. Some may question the need for as many classes as have been adopted in New York State; some may not approve of the detailed descriptions of the several classes. Others are likely to take exception to the concept of specific standards of quality and some of those agreeing with the establishment of standards will disagree on matters of detail.

The earliest example of stream classification in the United States, so far as can be recalled, was the action of the Sanitary Water Board of Pennsylvania in 1923 in dividing the waters of that state into three classes (1). The three classes may be described briefly as: (A) relatively clean and pure streams to be kept clean; (B) more or less polluted streams, but sufficiently clean to warrant preservation of cleanliness to permit their use for various purposes other than the removal of wastes; and (C) heavily polluted streams to be maintained just above the nuisance state. As compared with that of New York State, the Pennsylvania classification did not involve specific quantitative standards of quality and was the ultimate in simplicity. The Delaware River Compact of 1925, however, ventured to become more specific. Other stream classifications have been proposed or adopted for other regions, but none is as detailed or as complex as that of New York.

Mr. Dappert implies that municipalities and industries have desired definite and detailed requirements. Although it may be true that industry has asked for specific standards, the situation which may arise is likely to be similar to the Aesop fable in which the frogs asked for a king and received a stork, which promptly gobbled them all up.

Mr. Dappert discusses classification and standardization as one subject; "classes" and "standards" are almost invariably coupled in his paper. By implication at least, he considers that each must stand or fall with the other. It seems to the writer that there may be some hazard in this "love me, love my dog" point of view, particularly when classes and standards are adopted simultaneously and the standards are defined rather specifically in some respects but vaguely in other respects. This presents a somewhat paradoxical situation. Note the language of Rule 1 adopted by the New York Pollution Control Board pursuant to Article 6 of the Public Health Law. This rule reads:

"In making any test or analytical determinations of classified waters to determine compliance or non-compliance of sewage, industrial wastes, or other waste discharges with established standards, samples shall be collected in such manner, and at such locations as are approved by the Board as being representative of the receiving waters after opportunity for reasonable dilution admixture with the wastes discharged thereto."

This rule possesses a perfectly justifiable vagueness, which, however, is in contrast with the specific limits for certain quality characteristics established by the Board for the several classes of waters. A further example of vagueness coupled with definiteness lies in the fact that whereas limits for dissolved oxygen are given in specific terms, nothing is specified as to the time of year in which the limits are applicable or under what conditions of stream flow. If the quality limits are defined, should not the seasonal and flow conditions under which the standards are applied, be defined also? Is it not essential that all significant factors be taken into consideration and specified? Otherwise, hasn't there been a return to the necessity for applying engineering judgment, which was the starting point?

Reference is made by Mr. Dappert to the report of the Ohio Department of Health on the Miami River, partly with approval and partly with disapproval. As it happens, the writer made a rather careful sanitary survey of the Miami River above and below Dayton in 1923. As a result of this survey, a program of sewage and wastes interception and treatment was adopted by the city and approved by the State Department of Health. The conclusions and approval were based upon careful appraisal of the ascertainable facts and the exercise of engineering judgment. If Ohio had had a set of standards for the Miami River at Dayton, it is doubtful if the program would have been any different from that adopted.

Mr. Dappert states that standards should be expressed in definite terms only where there is valid justification therefor. This is sound, but one wonders why the "safe" limits for metallic elements are indicated as so much lower than those in the drinking-water standards of the U. S. Public Health Service. Although it is true that these limits are presented for guidance only, the chances are that they will be taken as specific requirements. If so, the speaker wonders how certain water supply reservoirs can be adequately treated with copper sulfate for algae control and meet the "safe" limit of 0.2 p.p.m. of copper.

In the matter of conditions and frequency of sampling, there has been opportunity to examine two of the reports dealing with the studies made by the New York State Department of Health for the purpose of classification and application of the standards adopted by the Water Pollution Control Board. These studies involved sampling and analyses at many stations along the course of the streams and their tributaries. The samples at any one station have been relatively few and in effect represent catch samples. Whether or not conditions were representative at the time of sampling may be open to question, although probably the judgment of the director of the study coupled with the sanitary survey and knowledge of local conditions was utilized.

The application of the New York State classification system is illustrated by the investigation of the sanitary condition of the surface waters of the Rondout River-Rondout Creek-Wallkill River drainage basin and the classification of these waters. This investigation was made in the fall of 1949 and the classification was adopted in June 1951. The investigation and report thereon were thoroughly executed. More than 200 stream samples were collected and analyzed from many sampling stations scattered over

the 865 sq. mi. of drainage area. As the result of this investigation the surface waters of the drainage area, streams, ponds, and lakes were given classification ratings at some 400 different points. Therefore, some bit of surface water was classified on the average every 2.16 sq. mi. If the future classification density over the whole of the state is to approximate that applied to this limited Rondout-Wallkill area, then eventually there will be about 23,000 points at which surface waters are classified. This raises questions as to how long it is likely to take to classify all the waters of New York State and how much it is going to cost.

The time involved in such an ambitious program may be so great that by the end of the first program of classification it will become necessary, because of changed conditions, to start on a second program, and so on *ad infinitum*. This would seem to add up to a very substantial cost and one wonders if the anticipated benefits will be commensurate with this cost.

Fundamentally, the stream classification standardization system as adopted in New York State may be objectionable to some people, not because of its technique or because of details with which they may not be in full accord, but because it is a further step towards the establishment of government by administrative regulations. Such people will claim that unconsciously but steadily the citizens of the United States are becoming more and more controlled in their activities by executive regulations promulgated by departments and bureaus, federal, state, and local. The multitude of specific regulations which now control the individual from the cradle to the grave is beyond the ken of any one man.

In the hands of able and honest men and as an intra-departmental administrative procedure to aid judgment, there can be little objection to a carefully prepared and reasonable classification-standards system. However, a rigid system of regulations, based on arbitrary standards and having the force of law, may be quite another matter.

Reference

1. Stevenson, W. L., "The Sanitary Conservation and Utilization of Water Resources." *Jour.*, Boston Soc. Civil Eng., **13**, 51 (1926).

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

PRODUCTIVE MAINTENANCE

Announcement by the General Electric Company of what is resoundingly termed a "Productive Maintenance" plan for industry points up in brief the principles of good maintenance as set forth in these pages from time to time in detail.

The program as offered calls for a thorough and systematized approach to the whole idea of equipment maintenance as a positive rather than a negative force. In fact, the job of maintenance is pointed out, not as something to be done as a necessary evil when emergency demands, but as a constructive factor in increasing productive output and efficiency.

The plan as offered recommends (1) an adequate staff of maintenance men, armed with (2) the tools needed to perform properly the functions of (3) regular, routine checks of operating equipment, and (4) planned outage of this equipment at regular, scheduled intervals. Rebuilding and modernizing of machines during these times of planned outage is intended to be done readily with (5) an adequate stock of mechanical and electrical renewal parts.

Here is a 5-point formula for successful maintenance, designed to keep equipment at peak operational efficiency while preventing that emergency repair job through advance planning for machine servicing needs. However, there is a sixth factor that should be added to the formulation—a factor that might be termed "implementation." In other words, preventive, productive, or any other kind of maintenance is no good unless someone—you—gets the program established and follows it through.

Among the most useful of the management tools suggested by the originators of the new service are equipment "biographical" cards, control records for the planned outages, and equipment inspection checklists. Actually these are nothing more than high-sounding names for the simple maintenance control records we have so long been urging each sewage treatment and industrial wastes treatment plant to adopt and maintain.

The "Productive Maintenance" plan is designed to get the most out of production equipment in industry. However, it is equally as adaptable to the "production" equipment of waste treatment plants. No fancy sales phrases should be needed to bring a realization of the importance of planned, conscientious maintenance procedures. And the importance of complete and reliable records will be evident if one thinks of the advantages to be gained in parts inventory control, reduced equipment down-time, improved efficiencies, and reduced maintenance man-hours at overtime rates.

Put your own "Productive Maintenance" program into high gear. All that is needed is to do all the maintenance things you've been thinking about and intending to do, and then to keep on doing them, with complete records, for continued effectiveness.

H. P. O.

SWINGING STANDPIPE FOR CLARIFIER MAINTENANCE

By H. H. Connally

Operator, Sewage Treatment Plant, Newberry, S. C.

To ease the task of cleaning the effluent troughs and weirs of the circular clarifiers at the Newberry, S. C., sewage treatment plant, the device shown in Figure 1 was designed and installed. Because the clarifiers are of the stationary bridge type, it was possible to run a water line out along the bridge to an upright pipe near the center of the tank. The top of the vertical leg is fitted with a swiveling joint to accommodate a horizontal extension, to the end of which a piece of ordinary hose is attached. By this means the operator is able to move the hose around the circumference of the tank for easy cleanup without having to trail a long length of hose around on the ground.

Almost any type of homemade swiveling joint can be used to enable the standpipe to be rotated. Excessive loss of water at the rotating joint when not in use is eliminated simply by placing the shutoff valve in a stationary pipe at the edge of the tank.

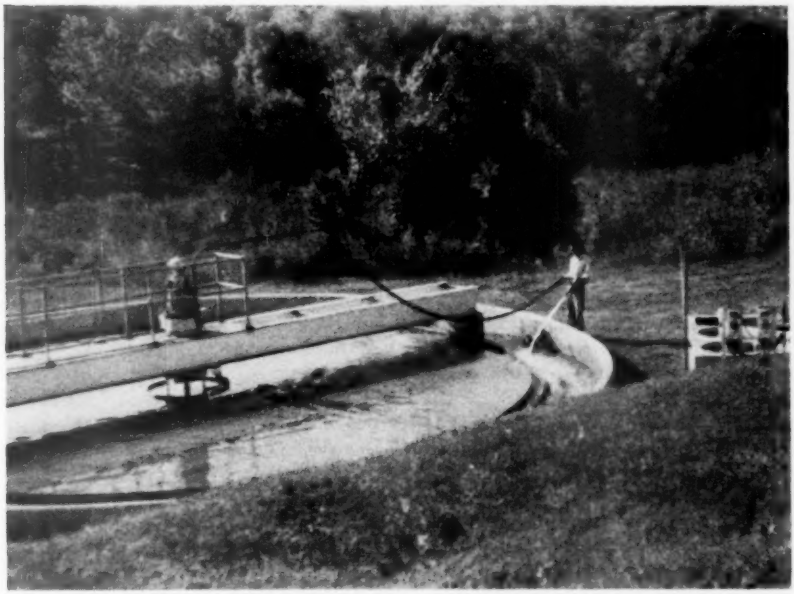

FIGURE 1.—Swinging standpipe on clarifier bridge simplifies cleanup.

THE DAILY LOG

Kenosha, Wisconsin

By Frank I. Vilen, *Superintendent*

July 15—The crew began the major task of painting the gas holder on one of the digesters. Much scraping and cleaning is required to prepare the surface. The waste burner has been shut off to keep the cover at its maximum height during this ticklish operation.

July 24—The gas holder is all shiny and resplendent in its new coat of aluminum. Spraying equipment is certainly wonderful to have—the painting gets done in a fraction of the time and the finished job looks much better than when done with brushes. The changeover to summer grade oil in all equipment was made today. At least that's one sign that it is getting warm!

August 15—The Wisconsin Park and Recreation group is in convention in our city. One of their scheduled visits was to the sewage treatment plant. The many complimentary comments were music to our ears, and make the crew feel that their "spit and polish" efforts are not in vain.

August 18—New drive chains and sprockets were installed on the cross collector drives on two of the clarifiers. The main collector chains also were inspected and a number of worn links were replaced.

September 2—The cylinder head ordered last February to replace a warped and leaky head on one of the gas engines finally arrived—after evidently having circled the globe several times. Of course, it turned out to be the wrong one, although I'm sure we sent in a complete description of the unit. This one is an inch higher and is not equipped with air starter ports. Called the factory, and found that ours is a special. They promised to send a head which will fit, but which we will have to build up with an extra gasket, as it will be ⅛ in. lower.

September 7—The new gas engine head has been received, installed, and apparently is working out O.K. Lesson: If you need something in a hurry, don't order it through the usual channels. Get on the phone and be sure you're talking to the head man and not to some office boy. A phone call will save a lot of time and money in the long run. We once held an order open for a 35¢ screwdriver for several months. Twenty minutes after calling the president of the company, we had our tool.

October 7—Yesterday established a new pumping record at 19.5 m.g. A southeast storm occasionally forces lake water back through the storm-water outfalls and into the interceptor. These should probably be equipped with gates, although this condition happens only very rarely. When we have a southeaster, the mouth of the 99-in. outfall builds up with sand and a crew must be dispatched to shovel it out.

October 14—Engineers from the State Board of Health visited the plant preparatory to starting a pollution survey of the areas adjacent to the city; these areas have grown rapidly in the past few years and many complaints of pollution and the dumping of raw sewage into creeks have reached the ears of local and state officials. Because the city is downstream from many of these watercourses, the pollution emanating from outside the city drains into back yards of Kenosha residences, causing nuisances, odors, rats, and a definite health hazard. These people have elected to live in the city and enjoy the benefits of sewers, sewage treatment, and garbage collection. They have a right to complain about a condition which is caused by the insanitary procedures of people in the adjacent

county areas and want something done about it, but quick.

October 16—Number 2 digester was taken out of service preparatory to cleaning. To compensate, raw sludge pumping to Number 1 was increased as this unit will have to furnish all the plant gas requirements while the other is out of service. This was computed on the basis of 6 cu. ft. per pound of volatile dry solids added; hope the ornery, cranky, old &%–'%%**!– comes up to expectations. The plant gas requirement totals 39,000 cu. ft. per day.

October 18—No. 2 digester cover was seated at 1 P.M. There was a little excitement shortly after, when the gas engines stopped and gas pressure dropped to zero. It was found that the pressure relief valve diaphragm had blown. This was replaced, and we were back in business in a hurry.

October 26—About 16 in. of sludge was left in the bottom of the digester. This was not as heavy as had been anticipated and it is being moved without much trouble. Up to ¼ in. of scale was found on the heating coils—ergo, the poor heat transfer. The scale was removed easily with chipping hammers. The "in" temperatures never are allowed to get above 135° F. However, we've talked to a colleague who operates a plant a few miles away and who claims they use much higher temperatures—up around 150°—and have no trouble with scale!

November 4—Heating coils, trusses, pipe supports, and all other ironwork in the shutdown digester in good condition. The only repair job was to fasten a pipe support that had come loose from the wall.

November 8—The digester is back in service and making gas. We purged it a number of times until sure all the air was removed. Gas was then routed to the waste burner for a couple of hours before the digester was placed back in service.

November 16—A good opportunity arose today to take an end-of-year inventory of stock and supplies. As a result, a number of items regularly used at the plant were ordered from funds still available this year.

December 15—Raw sludge volatiles were down to 44 per cent—we've pumped better sludge than this out of the digesters.

January 3—To work this rainy, gloomy morning full of New Year's cheer and loaded with resolutions. No doubt these will soon be forgotten and buried in the details of daily chores. Annual overhaul of the gas engines was begun. Will grind and reseat valves; install new rings, plugs, and gaskets; and check clearance and wear.

January 10—Gas production dropped from 43,000 cu. ft. on the first to 26,000 cu. ft. today. Digester temperatures were about normal, but the sludges were heavy and the volatiles low.

January 12—Part of our digestion and gas production difficulties can be attributed to an annual cleaning of the Pike Creek interceptor. This large sewer, which meanders along the bank of Pike Creek, has settled considerably over the years, and it is the custom to clean out the accumulated muck and silt each winter. We doubt the efficacy of this, as the sewer undoubtedly soon silts up again in these low places. Also, we feel that it is harmful to the treatment plant, as a large amount of the lighter sewage solids and organic matter is lost, and the remainder diluted with a great deal of water in the flushing operation. We do know that an unusual amount of fine clays and sand is washed to the plant at these times. At least, the cleaning is done at a bad time of year for plant operation; a time when every pound of volatile matter is needed. Our sewage is normally quite dilute (raw sewage suspended solids 150 p.p.m.; B.O.D. 101 p.p.m.) and, consequently, the power and fuel requirements are out of step with the gas production during winter months.

January 14—The interceptor cleaning is about complete, but the clarifier hop-

pers have an accumulation of clay and muck which is so heavy we can't move it. This means dewatering all the clarifiers and cleaning them out.

January 24—Ran a series of samples in the laboratory for chrome and copper. These samples were picked up at various industrial locations, all of which are engaged in plating work; no appreciable amounts of either metal were found. We still get some copper and last year averaged 3,500 p.p.m. in digester sludges, as dry solids. It is believed that up to 6,000 p.p.m. can be tolerated and still get pretty good digestion. Hmm, I wonder if exposure to copper will develop a strain of bugs in the digesters that have more tolerance to it? If so, what happens when a digester is cleaned and emptied? Of course, we seed ours from the other digester. What is needed is an all-purpose bug—one that is able to resist all possible toxins in sewage and isn't too lazy to make lots of gas. There's a challenge for some smart bacteriologist. If anyone goes to work on this, I also suggest a built-in overcoat for the bug to resist the arctic Wisconsin winters.

January 25—The dry weather flow is around 11.4 m.g.d. This is considerably more than had been anticipated when we began treating the city's total flow last May; also, it is 14 per cent above the plant design flow. About 3 m.g.d. of this is cooling water from a rolling operation in a local mill. It certainly is not sewage and serves only to dilute and increase the plant load.

February 14—During the recent industrial wastes sampling iron pickling waste discharges were found with a pH as low as 3.0. This waste is intermittently discharged into the sewer from a holding tank. The low pH does not bother plant operations, as the raw sewage is quite normal in this respect. A look into the sewer in the immediate vicinity of the discharge indicated very little damage. This is a large vitrified pipe; except for some mortar missing from joints, the sewer seemed to be in good shape. The sewer is many years old and apparently has stood up well in spite of the acid waste. However, the findings were reported to the Director of Public Works who is concerned with the maintenance of the sewer system.

February 24—The discouraging battle of statistics is on again. Average daily flow this month was 18 m.g.d.; suspended solids reduction, 33 per cent; volatile matter, around 55 per cent (normal above 60 per cent); and total daily gas production, 18,500 cu. ft. A repeat operation must be performed again to dewater the clarifiers and remove an accumulation of heavy mud, which the pumps cannot handle.

March 3—Completed cleaning the clarifier hoppers. The total precipitation for the past two months was 6.55 in., which is 4 in. more than the previous average for the same period.

April 24—Just 18 months ago the exhaust gas muffler was rotated, placing the top side down to get more wear out of it. It has now failed and a new one, fabricated from a corrosion-resistant alloy, is being installed.

May 8—Officials of a local company today offered the information that they are studying the possibility of pretreatment of their iron pickling wastes. Simplicity of operation, economy, and a minimum of sludge handling are their main concerns. We helped steer them in this by furnishing references and names of those who have done work in this field.

June 3—We have been plagued with sizable quantities of oil on several occasions. Today the scum troughs were full—an estimated 20 bbl. The trick is for the industry to keep it out of the sewers. This can be difficult in a large and complex plant, as the individual loss is small and many locations and employees may be involved. However, we have found all officials most cooperative and just as concerned with the problem as are we at the treatment plant.

June 27—One of the sludge pumps was changed over to a patented type of packing. Also, the other was repacked with our regular graphited material for comparative tests. It is claimed that the new rings will give much longer service, although the first cost is a little more.

July 1—This morning the air compressor motor was found burned out. On inspection it was discovered that the bleeder valve had stuck and the motor had been forced to start against a load. The condition was remedied to prevent reoccurrence, but the motor had to be completely overhauled.

August 14—Public employees have long been aware that like the fishes they swim around in a glass bowl, subject to the often biased scrutiny of the citizenry. Consider the case of one of our Water Department employees who was seen driving a city car to the lake, apparently to fish, armed with a cane pole. We hope the complexion of the over-zealous reporter of this incident changed to a deep magenta when it was revealed that the fishline ended in a bottle instead of a hook and that the employee was fishing for pollution and not perch. The incident occurred during a period of lake water sampling and was duly reported in the local press. All had a good laugh except the character who (we hope) will hereafter wait to count the fish after they are caught!

OPERATION AND MAINTENANCE OF CENTRIFUGAL PUMPS *

By R. B. Riddle

Utilities Superintendent and City Engineer, Frederick, Okla.

The chief advantages of the centrifugal pump over other types of pumps are its simplicity, reliability, and ease of operation. Another important feature is that the discharge is smooth and continuous, and free from shocks and pulsations. Because the centrifugal pump is free from vibration, it does not require an elaborate foundation. Moreover, the centrifugal pump possesses the merits of high speed, occupies less space, is lighter in weight, and generally costs less than other types of pumps. The fact that the discharge from a centrifugal pump may be shut off by closing a valve in the discharge pipe without dangerous pressures being introduced or requiring the motor to be shut down is another great advantage.

* Presented at 24th Oklahoma Water, Sewage and Industrial Wastes Conference Short Course; Stillwater, Okla.; Nov. 27–Dec. 1, 1950.

Installation

In the installation of a centrifugal pump there are several important operations that must be given careful attention. These are as follows:

1. Set the base plate with the pump and the prime mover on a solid foundation, preferably of concrete, level carefully, grout the base plate in, and allow to set. See that the pump and the motor are in line, and that the shaft turns easily by hand after the anchor-bolt nuts have been tightened.

2. When the pump is set, connect the suction and discharge pipes; see that these pipes are self-supporting, in order to avoid strain on the pump and ensure proper alignment. Be sure the pump and the motor are dowel pinned to the base when they are in proper alignment.

3. Locate the pump as near the supply intake as possible. The maximum

suction lift, including pipe friction, varies with the size of pump and the liquids to be handled. Hot water or heavy liquids must flow to the pump under a positive head, this head varying according to the difference in temperature of the liquid or the viscosity of the liquid.

4. Never use pipe sizes smaller than the pump calls for. For long pipelines, use pipe two or three sizes larger. Make the suction pipe as short as possible and avoid bends and elbows. Make sure that there are no air pockets in the line, and that the suction pipe is absolutely air tight.

5. Place a check valve and a gate valve in the discharge pipe as close as possible to the pump. The check valve must be placed between the gate valve and the pump in order to be able to inspect or repair the check valve.

6. Always provide a strainer on the end of the suction line. This protects the pump from being choked by foreign matter and ensures safe operation.

7. To pack stuffing boxes, do not draw the glands up tight, but allow a reasonable leakage, which lubricates the packing and prevents the shaft being corroded. Pipe the leakage from the tap in the bearing bracket to a sewer or drain.

8. Before starting the pump, clean the bearings with gasoline or kerosene and fill the oil reservoirs with high-grade lubricating oil, as high as the tap of the oil gage indicates.

Operation

In operating a centrifugal pump, certain basic rules must be remembered, as follows:

1. The pump must always be primed before starting, otherwise the interior parts, which depend upon the water for lubrication, will be injured. Never run a centrifugal pump empty.

2. As soon as the case is primed, the pump should be started with the discharge valve closed and brought up to speed.

3. Open the gate valve slowly until the desired quantity of water is obtained. Failure of the pressure to increase with the speed indicates air in the pump casing. In this case, stop the pump and prime again.

4. As long as the water and, consequently, the case does not heat up excessively, due to friction produced by the rotation of the impeller, the centrifugal pump may be operated with a closed discharge valve. In contrast with displacement pumps, no by-passes are required.

5. Always run the pump in the direction of the arrow cast on the case. Centrifugal pumps can be run only in one direction.

6. During the operation of the pump, stuffing boxes and bearings must be inspected occasionally. The centrifugal pump does not require any other attention except to remove foreign material caught on the impeller.

7. If the pump is to be idle for long periods, it should be taken apart, cleaned, and oiled. This prevents the parts from rusting together and preserves their condition.

8. If the pump is exposed to freezing temperature, it should be drained immediately after stopping.

Operating Problems

The common problems that arise in centrifugal pump operation may be classified and identified according to the following:

1. If, after starting the pump, it throws a little water at the first few revolutions and then churns and fails to discharge more, it is evidence that the air is not all out of the pump and the pipes, the suction list is too great, there are pipe leaks, or the suction is long and the discharge head is insufficient.

2. If, when first started, the pump throws a full stream for a few minutes and then fails, it is caused by failure

of the supply or recession of the water below the suction limit. The remedy for this latter condition is to lower the pump.

3. If the pump delivers a full stream of water at the level of the pump, but fails to pump to a higher discharge point, the speed of the pump is too low.

4. If the pump starts a full stream, and then the discharge decreases very slowly until the pump fails to deliver any water, it is caused by an air leak at the packing gland.

5. If the pump delivers a full quantity for a few hours and fails, the speed and water supply being unchanged, the suction pipe or the impeller is obstructed.

6. If, when running, there is a heavy vibration, the shaft has been sprung, the pump is out of alignment, or an obstruction has lodged in one side of the impeller.

7. If the bearings heat unduly, the bearings lack oil, there is an end thrust, or the belt is too tight.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Biennial Report of the Hartford (Conn.) Metropolitan District for the Years 1949 and 1950 [1, 2]

By George H. Craemer, *Division Engineer in Charge*

Grit Chambers

Each of the four grit chambers (one spare, one extra for maximum flow, and two for normal flow) is equipped with endless chain scrapers and a screw elevator washer. The grit is removed from the chambers after any appreciable rain causing an increase in flow through the plant, and approximately every two weeks during dry weather flow. Previously it had been found advantageous to dewater the channels when removing grit. However, addition of a water feed to the bottom of the grit hoppers has aided in removing much of the organic material, doing away with the necessity of dewatering the channels when removing grit.

Sludge Gas Composition

With proper digestion, sludge gas analyses show the constituents to vary as follows:

Constituent	Min. (%)	Max. (%)	Av. (%)
Carbon dioxide	30.5	35.8	33.3
Illuminants	0.0	0.3	0.2
Oxygen	0.1	0.6	0.4
Hydrogen	0.0	0.6	0.2
Carbon monoxide	0.0	0.3	0.1
Methane	52.6	66.0	61.6
Ethane	0.0	2.5	0.6
Nitrogen	0.3	10.5	3.3
Hydrogen sulfide	0.013		trace
Net B.t.u.	478	600	576

Date	Moisture (%)	Dry Solids			B.t.u.	
		Total (%)	Volatile (%)	Ash (%)	Dry Basis	Wet Basis
July 22	83.0	17.0	88.7	11.3	8,329	1,416
July 30	71.8	28.2	92.4	7.6	10,922	2,080
Aug. 6	74.8	25.2	91.6	8.4	9,006	2,270
Aug. 28	79.3	20.7	89.3	10.7	9,983	2,066
Aug. 29	80.6	19.4	89.9	10.1	—	—
Aug. 30	74.4	25.6	93.9	6.1	8,667	2,219
Sept. 10	74.8	25.2	93.2	6.8	10,351	2,608
Sept. 19	79.8	20.2	88.7	11.3	9,683	1,947
Sept. 24	78.9	21.1	95.0	5.0	8,650	1,825
Av.	77.5	22.5	91.4	8.6	9,449	2,054

[1] Recipient of FSIWA 1951 Hatfield Award for plants serving more than 100,000 population.

[2] For last previous extract see This Journal, **18**, 4, 737 (July, 1946).

Garbage Analysis

Five-gallon composite samples taken from garbage collectors' wagons during the period July-September were ground by means of a large-sized kitchen grinding mill and tests were run on initial 300-g. samples. Partial results are shown in table on page 329, lower part of right column.

Table I is a summary of the plant operating data for 1949 and 1950.

TABLE I.—Summary of 1949 and 1950 Operating Data at Hartford, Conn.

Item	1949 Average	1950 Average
Estimated population served	220,000	220,000
Sewage flow (m.g.d.)*	29.6	29.5
Operating time (% of year)*	77.4	75.4
Number of employees	22	22
Screenings (cu. ft./mg.)	2.3	2.0
Grit (cu. ft./mg.)	1.6	1.8
Raw sludge removed:		
Total (m.g.)	16.49	15.91
Moisture (%)	93.2	93.3
Dry solids (lb./day)	32,600	32,540
Dry solids (lb./m.g.)	1,100	1,100
Volatile solids (%)	72.0	69.4
Detention in tanks (hr.)	2.78	2.94
Ether soluble grease (%)	25.2	27.7
Digestion tank data:		
Temperature (° F.)	98.0	94.0
pH	6.9	6.9
Hot water, in (° F.)	141	147
Hot water, out (° F.)	123	129
Total sludge removed (m.g.)	7.73	7.20
Moisture of sludge removed (%)	94.8	94.5
Volatile solids (%)	50.5	49.5
Ether soluble grease (%)	11.4	15.6
Sludge gas data:		
Gas produced, total (10^6 cu. ft.)	52.04	48.53
Gas used, total (10^6 cu. ft.)	21.53	30.19
Production per capita per day of operation (cu. ft.)	0.84	0.88
Carbon dioxide content (%)	34.0	34.0
Net heating value (B.t.u.)	570	570
Elutriated sludge data:		
Total sludge from elutriation tanks (m.g.)	6.08	6.23
Moisture (%)	94.9	94.7
Total dry solids (10^6 lb.)	2.62	2.80
Volatile solids (%)	48.2	46.5
Vacuum filter operation data:		
Total operation (days)	105	112
Total operation (hr.)	1,288.8	1,361.5
Total $FeCl_3$ used (lb.)	51,236	61,531
Total $Al_2(SO_4)_3$ (lb.)†	3,660	—
$FeCl_3$, dry basis (%)	1.78	2.22
$Al_2(SO_4)_3$, dry basis (%)†	4.41	—
Total sludge cake produced (10^6 lb.)	7.88	8.42
Cake moisture (%)	66.3	66.9
Rate (lb./sq. ft./hr.)	6.20	6.01
Total dry solids in cake (10^6 lb.)	2.62	2.80
pH of filtrate:		
With $FeCl_3$	6.2	6.1
With $Al_2(SO_4)_3$	4.2	—
Sludge cake produced, total (cu. yd.)	4,638.1	4,949.2

TABLE I.—Summary of 1949 and 1950 Operating Data at Hartford, Conn.—*Continued*

Item	1949 Average	1950 Average
Operating cost data ($):		
Total	113,031.26	114,822.89
Per m.g. treated	13.52	14.14
Per capita per year	0.51	0.52
Analytical data:		
Suspended solids:		
Influent (p.p.m.)	186	189
Effluent (p.p.m.)	70	71
Reduction (%)	60.9	61.9
Raw sludge:		
Moisture (%)	93.1	93.3
Volatile solids (%)	72.0	69.4
Digested sludge:		
Moisture (%)	94.4	94.4
Volatile solids (%)	50.5	49.5
Elutriated sludge:		
Moisture (%)	94.9	94.7
Volatile solids (%)	48.2	46.5
Reduction in volatile matter by digestion (%)	61.1	57.0
Digestion and filtration alkalinities (p.p.m. as $CaCO_3$):		
Digested sludge	2,875	2,907
Elutriated sludge	245	284
Elutriate	867	892

* Plant closed during all or part of certain months; river elevation above operating level.
† Used only during one month in 1949.

Eighteenth Annual Report of the Minneapolis-St. Paul (Minn.) Sanitary District for the Year 1950 [1, 2]

By Kerwin L. Mick, *Chief Engineer and Superintendent*

A total of 41,495 m.g. of sewage was treated by the plant during 1950, averaging 122.3 m.g.d. A total of 36,845 cu. ft. of screenings and 192,910 cu. ft. of grit were removed. During the year, 115,772 tons of filter cake were produced containing 35,637 tons of dry sewage solids.

From an estimated tributary population of 870,000 in 1950, the following per capita values obtained:

(1) Sewage flow, g.c.p.d.—140.

(2) Suspended solids, raw sewage, lb. per cap. per day—0.32.

(3) B.O.D., raw sewage, lb. per cap. per day—0.24.

Assuming 0.17 lb. of 5-day B.O.D. per capita per day for domestic sewage only, the population equivalent of the sewage and wastes received at the plant during 1950 was 1,260,000, or 45 per cent greater than the estimated population of 870,000. Industrial wastes account for the major part of this difference, and according to these figures would amount to 31 per cent of the pollution load on the plant.

Sludge Conditioning and Filtration

Chemicals used for sludge conditioning during 1950 were ferric sulfate, expressed as ferric chloride, fed at an average dosage of 0.98 per cent of the weight of the dry sludge solids, and lime at an average dosage of 2.95 per cent expressed on a calcium oxide basis.

[1] Recipient of FSIWA 1951 Hatfield Award (previous winner) for plants serving more than 100,000 population.

[2] For last previous extract see This Journal, **21**, 2, 334 (Mar., 1949).

The average life of filter cloths during 1950 was 482 hr., compared with 539 in 1949, and 533 in 1948, 413 in 1947, 492 in 1946, 325 in 1945, 474 in 1944, 461 in 1943, 493 in 1942, 355 in 1941, 326 in 1940, and 168 in 1939.

The lower cloth life in 1950 is believed to have been at least partly due to considerable trouble experienced during the year with the winding wires working loose on the filters, breaking and causing excessive wear on the cloths and making frequent re-winding necessary. It was finally concluded that the loose wire troubles were due partly to the winding rig having become worn and partly to the filter cake discharge plates being clamped too tightly against the wire. Since the winding rig was rebuilt and the discharge plates set loosely against the wire, the loose wire troubles have practically ceased.

No changes in filter washing procedure were made during the year. After trying various washing frequencies, in the range between the former practice of washing the filters at least once every 4 hr. and continuous washing, the following practice has been in effect since November, 1947, as representing the most economical procedure. The filters are washed at least once each hour for at least one revolution of the drum (about 5 min.), and may be washed oftener under difficult filtering conditions at the discretion of the operator. Thus, the maximum interval between filter washings has been progressively decreased from 24 hr. or longer when the plant started operation in 1938 to 8 hr., to 4 hr. in 1942, to continuous washing with plant effluent in 1945, and now up to 1 hr. as the practice since November, 1947. The wash-water pressure ranges from 50 to 70 lb. per sq. in.

Industrial Waste Studies

No apparent heavy discharge of troublesome industrial wastes into the Sanitary District system was observed throughout the various phases of plant operation during most of 1950. However, on July 27 approximately 6 bbl. of heavy tar were received at the plant, along with the sewage, causing major operational difficulties. The tar lodged in the bar screens, sheared pins on the screen cleaning mechanisms and made it necessary to by-pass the entire sewage flow directly to the river for 5 hr. while the screens were manually cleaned. Again, on August 18, another heavy discharge of tar arrived at the plant and it was necesssary to bypass three-fourths of the sewage flow for a period of 3 hr. Laboratory examination of this material by the District staff and two other laboratories resulted in the conclusion that it was an asphalt product, possibly road patching asphalt containing a small amount of tar. All possible sources from which this material could have been discharged were investigated, but with no positive identification. Newspaper publicity, however, regarding these discharges and their detrimental effect on the treatment plant operation may have been effective, inasmuch as no further discharges of this nature were encountered during the balance of the year. In addition, the newspaper item reported on the numerous children's toys, rubber balls, false teeth, etc., received at the plant. As a result, a number of false teeth plates which had accumulated were claimed and probably put "back in use."

Considerable quantities of wood chips were received at the plant during the period October—December. The peculiarity of such discharges lay in the fact that the wood chips were uniform in size (approximately 1 in.) and would settle out in the grit chambers, whereas normally such material would float and be discharged into the scum trough. Occasional discharges of these chips would not greatly affect removal operations, but as these discharges became daily occurrences, and in greater quantities, fear was expressed that their

continuation would reduce the grit chamber capacity for normal operation. Laboratory examination disclosed that the wood chips had undergone an industrial leaching-out process prior to disposal into the sanitary system. Sanitary District investigation, with the cooperation of municipal sewer department personnel, disclosed the source of the discharges, which were not a normal procedure with the offending industry, but rather due to careless operating technique and resulted in definite financial loss to their production. Remedial measures were immediately taken and the discharges discontinued.

Miscellaneous

In April, the practice of conducting a planned shutdown of the treatment plant during periods of high water in the spring to ensure dependability of operation during the critical summer and winter months was continued. In addition to the inspection of all the equipment at the plant, such shutdowns are necessary to inspect the intercepting sewers and control stations, which are inaccessible except during such times. The sludge conditioning tank and distribution piping to the filters were also revised during this period, in preparation for the installation of two additional vacuum filters later in the year.

During 1950 none of the fresh sludge cake production was issued to farmers for fertilizer purposes, the State Department of Health having declined to approve the continuance of this practice, which had been carried on for a number of years prior to 1947 on an experimental basis during the fall and winter months only. However, small users are still permitted to obtain some of the aged cake which has been stockpiled for two years or more before use. The quantity stockpiled for fertilizer use has averaged about 360 tons (dry basis) per year over a 10-year period, or only about 1% of the total annual production.

The average flow for 1950 was 122.3 m.g.d., a decrease of 2.5 m.g.d. from the 1949 flow of 124.8 m.g.d., with the maximum of 159.8 m.g. being received on August 15.

The solids content of the sewage increased, with the total solids averaging 770 p.p.m. and the suspended solids 275 p.p.m. compared with 725 and 270 p.p.m., respectively, in 1949. The B.O.D. increased to 210 p.p.m. The volatile content of the suspended solids increased to 75.2 per cent for the year, establishing a new record high since the start of operations in 1938.

The extreme ranges in raw sewage strength during the year are also of interest, in contrast with the average values. The B.O.D. was at a minimum of 63 p.p.m. on Sunday, March 26, due to the dilution of the normally weak Sunday sewage by heavy rains and thaw flows the same day. The average total precipitation recorded for the Twin City area on that day was 0.62 in. The maximum B.O.D. of 310 p.p.m. occurred on Monday, January 9. In terms of suspended solids the raw sewage strength was at a minimum of 125 p.p.m. on Sunday, May 7, and a maximum of 550 p.p.m. on May 5, when the sewage was observed to contain unusual quantities of grit flushed through the intercepting sewer by an extremely heavy rain during most of the day.

The screenings belt was replaced in April, after 12 years of service. To ensure proper storage of spare conveyor belts, several stands were made this year to carry the weight of the rolled belt on an axis through the center of the roll.

Since the use of ferric sulfate was started (for sludge conditioning) in 1947, there are times during humid weather when movement of this chemical from the storage bins in the screen and grit chamber building through the pneumatic conveyor system to the filtration and incineration building has caused considerable trouble. As ferric sulfate is slightly hygroscopic, a hard build-up

TABLE II.—Summary of Operating Data for 1950 at Minneapolis-St. Paul, Minn.

Item	Average
Rainfall (in.)	23.03
Est. tributary population	870,000
Equiv. pop.	1,260,000
Sewage flow (m.g.d.)	122.3
Screenings (cu. ft./m.g.)	0.9
Grit removal:	
Amount (cu. ft./m.g.)	4.6
Volatile solids (%)	12.8
Dissolved oxygen (p.p.m.):	
Raw sewage	0.95
Settled effluent	4.55
Settling tank detention (hr.)	1.3
B.O.D., 5-day:	
Raw sewage (p.p.m.)	210
Settled effluent (p.p.m.)	130
Removal (%)	38.3
Suspended solids:	
Raw sewage (p.p.m.)	310
Settled effluent (p.p.m.)	80
Removal (%)	74.2
Settleable solids:	
Raw sewage (ml./l.)	6.5
Settled effluent (ml./l.)	0.3
Removal (%)	95.7
Volatile solids (%):	
Suspended, raw sewage	75.2
Susp., settled effl.	75.9
Total, raw sewage	46.3
Total, settled effl.	36.7
Raw sludge:	
pH	6.0
Total solids (%)	7.8
Volatile solids (%)	69.9
Thickened sludge:	
pH	5.9
Total alkalinity (p.p.m.)	1,100
Total solids (%)	8.8
Volatile solids (%)	69.3
Filter cake:	
Total solids (%)	31.3
Volatile solids (%)	66.2
Produced (wet tons/day)	343.4
Produced (dry tons/day)	107.6
Conditioning chemicals:	
CaO (lb./100 lb. dry sol.)	2.95
$FeCl_3$* (lb./100 lb. dry sol.)	0.98
Sludge filter rate:	
Wet cake (lb./sq. ft./hr.)	10.6
Wet cake (lb./sq. ft. filter area used)	0.93
Incineration:	
Combustibles (tons/day)	69.1
Moisture evap. per ton of combustibles (tons)	3.5
Ash produced (dry tons/day)	35.4
Power (kw.-hr./ton dry sol.)	10.5
Fuel oil (gal./ton dry sol.)	0.44
Filter cake disposal:	
For fertilizer, total (dry tons)	1,071
Incinerated (dry tons/day)	104.4

* Ferric sulfate used, but calculated to equivalent $FeCl_3$.

has formed at times in the 4-in. underground line. An improved hopper at the base of the bins and a method of flushing the conveyor line with water and then drying it with warm air have improved these conditions considerably. This year two cross rods were welded into the inlet of the tube at the hopper, reducing the plugging due to hard lumps that form occasionally in the sulfate.

Sludge Pipe Cleaning

Beginning about two years ago, a semi-hard, greasy build-up has formed in the 8-in. raw sludge lines from the pumps to the concentration tanks, and in the 6-in. sludge lines from the concentration tanks to the bucket elevators. Flushing with large quantities of water did no good. It was necessary to open and clean these lines with a rotating cable-and-knife pipe cleaning machine every two or three months. There has seldom been much build-up in the pump suction lines, and for the first 9 years none in the pressure lines. In May, a "go-devil" was tried out and later purchased. This machine is similar to the type used so successfully at Cleveland, Ohio. An old filter cloth is fastened around the outlet end of the pipe to be cleaned, making a large bag. This confines most of the clean-up work to a small area. This method of cleaning the pipes has reduced the manhours and much cleaning work necessary with the former method.

TIPS AND QUIPS

No Mistake

No, the captions on Figures 1 and 2 are not interchanged; they mean exactly what they say. In fact, they were purposely written that way to attract attention to the interesting phenomenon depicted.

As part of an investigation of the causes of frothing in activated sludge plants being carried on by C. H. Scherer, chemist of the San Antonio, Tex., sewage treatment plant, it was decided to test the effects of adding synthetic detergent to the aeration tanks. More than 2,800 lb. of a syndet (Procter and Gamble's "Tide") were added to one aeration tank without causing excessive frothing. Calculated

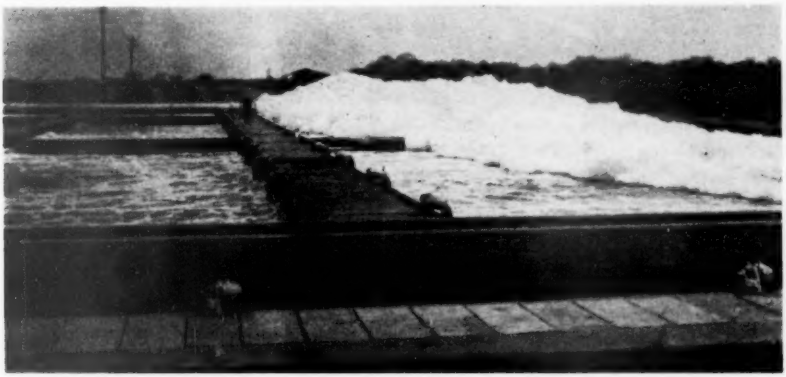

FIGURE 1.—Froth condition at aeration tank with no detergent added.

FIGURE 2.—Froth condition at aeration tank with 250 p.p.m. detergent added.

on the basis of raw sewage and return sludge flow, a range of syndet concentrations from 10 to 250 p.p.m. was investigated. Figures 1 and 2 show some of the extremes observed during the work.

Figure 1 shows excessive frothing intentionally caused in one aeration tank by lowering the solids content of the mixed liquor. No detergent had been added, but the mixed liquor solids were in the low range of 200 to 300 p.p.m. (no sludge had been returned since the previous afternoon).

Figure 2 normally would be thought of as being contrary to all frothing experience with syndets. In this case the syndet concentration actually added, over and above any already in the raw sewage, was 250 p.p.m. However, the mixed liquor solids concentration was 2,900 p.p.m., which Superintendent W. N. Wells says "is admittedly a little higher than the 2,000- to 2,600-p.p.m. range usually carried in the aeration tanks and with which little difficulty is experienced with foaming (frothing).

Additional tests with low concentrations are being carried on and other tests are in progress to determine if the detergents concentrate in the solid phase of the sludge or remain in the liquid phase. A full report on the work is expected soon for publication in THIS JOURNAL.

Protection for Chromium Plate

Frequent washings and occasional applications of a film of light lubricating oil (about S.A.E. 10–W) are all that are necessary to preserve the bright look of chromium-plated parts, even of such exposed items as automobile bumpers, handles, and trim parts. Waxy body-finish compounds also may be used, according to plating engineers of the American Electroplaters' Society, although these materials are somewhat less effective than oil.

Suggested procedures include:

1. Wipe clean, dry, chromium-plated surfaces thoroughly with an oil-dampened cloth three or four times during winter months and at least once in summer. Excess oil may be wiped off with a dry cloth so that the luster of bright work is not impaired.
2. Remove salt or calcium chloride from plated surfaces frequently.
3. If corrosion is already visible on plating, rub it with a damp cloth. A mild scouring powder or an enamel polish may be helpful. Rinse thoroughly and apply an oil film. (Do not scour hard enough to remove protective plastic coatings on recent plating of auto parts, as war shortages have forced use of thinner platings than are normally used.

Declassified Information

Among the top secret statistics we've long had to be so careful not to divulge are those pertaining to the number and occupational classifications of the lady members of the Federation. Just why the information should have been so hush-hush is unknown, unless it was simply that no one knew.

Now, however, the veil has been lifted and the enemy, if any, can get little aid or comfort from the knowledge that 10 of the 5,248 members on December 31, 1951, were of the gentler sex. Of the 10, four were employed in sewage treatment plant laboratories, three with State Health Department laboratories, and one each with a consulting firm, the AEC, and the USPHS. All are chemists, bacteriologists, or laboratory technicians.

Federation of Sewage and Industrial Wastes Associations

Annual Year Book and Directory

1952

OFFICERS

PAST PRESIDENTS

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ANNUAL MEETINGS AND CONVENTIONS

DIRECTORY OF COMMITTEES

MEMBERSHIP SUMMARY

DIRECTORY OF MEMBERS

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS, INC.

325 Illinois Building, Champaign, Ill.

1951–52 OFFICERS

President: Earnest Boyce

Vice-President: E. Sherman Chase

Treasurer: W. W. DeBerard

Executive Secretary-Editor: W. H. Wisely

Advisory Editor: F. W. Mohlman

PAST PRESIDENTS

Charles A. Emerson.....1928–41
*Arthur S. Bedell.....1941–42
George J. Schroepfer.....1942–43
A. M. Rawn.....1943–44
Albert E. Berry.....1944–45
John K. Hoskins.....1945–46
Francis S. Friel.....1946–47
George S. Russell.....1947–48
V. M. Ehlers.....1948–49
A. H. Niles.....1949–50
R. E. Fuhrman.....1950–51

HONORS AND AWARDS

Honorary Members

The qualifications for Honorary membership in the Federation are set forth in Article II, Section 4 of the By-laws. Honorary Members are elected upon recommendation by a committee comprising the President and four latest Past Presidents, the senior Past President as chairman, in accordance with a policy adopted by the Board of Control on October 23, 1943. Honorary Members elected to date are as follows:

Charles Alvin Emerson.....1941
*Arthur S. Bedell.....1942
Julius W. Bugbee.....1942
Langdon Pearse.....1942
Charles Gilman Hyde.....1943
Howard Eugene Moses.....1943
Floyd William Mohlman.....1944
Willem Rudolfs.....1945
William John Orchard.....1946
F. Wellington Gilcreas.....1948
Wilford Willis DeBerard.....1950

The Harrison Prescott Eddy Medal

The Harrison Prescott Eddy Medal is awarded annually to a member of any Member Association of the Federation for outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment, as comprehensively described and published during any stated year in SEWAGE AND INDUSTRIAL WASTES. The award commemorates Harrison Prescott Eddy, a famous engineer and a pioneer in the art of sewage treatment.

Past recipients of the award are:

Harry Willard Gehm.....1943
John Raymond Snell.....1944
Lloyd R. Setter.....1945
H. Heukelekian.....1946
Richard Pomeroy and Fred D. Bowlus.1947
F. W. Kittrell and O. W. Kochtitzky, Jr.....1948
John W. Hood.....1949
Daniel A. Okun.....1950
Peter S. S. Dawson and Samuel H. Jenkins.....1951

* Deceased.

The George Bradley Gascoigne Medal

The George Bradley Gascoigne Medal is awarded annually to a member of any Member Association of the Federation for outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated operational problems, as comprehensively described and published during any stated year in SEWAGE AND INDUSTRIAL WASTES. This award is in memory of George Bradley Gascoigne, a prominent consultant from 1922 to 1940, who demonstrated an unusual interest in matters of sewage works operation.

Past recipients of this award are:

Kerwin L. Mick.....1943
James T. Lynch and Uhl T. Mann....1944
John D. McDonald.....1945
LeRoy Winfield Van Kleeck.....1946
Leon S. Kraus.....1947
David P. Backmeyer.....1948
Wilbur N. Torpey.....1949
Clarence E. Keefer.....1950
Leonard S. Hillis.....1951

The Charles Alvin Emerson Medal

The Charles Alvin Emerson Medal is awarded annually to a member of any Member Association of the Federation "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Federation of Sewage and Industrial Wastes Associations in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc." This award honors Charles Alvin Emerson, who served as President of the Federation from 1928 to 1941 and holds the distinction of being its first Honorary Member.

Past recipients are:

Floyd William Mohlman.....1943
Willem Rudolfs.....1944
Harold Warner Streeter.....1945
F. Wellington Gilcreas.....1946
Langdon Pearse.....1947
LeRoy Winfield Van Kleeck.....1948
William J. Orchard.....1949
Morris M. Cohn.....1950
Howard Eugene Moses.....1951

The Industrial Wastes Medal

The Industrial Wastes Medal was established in 1949 to be awarded annually in the form of a plaque for the most outstanding contribution by an industrial employee on any aspect of industrial wastes control, as published in SEWAGE AND INDUSTRIAL WASTES during the year preceding the award.

Past recipients are:

Roy F. Weston, Robert G. Merman and Joseph G. DeMann.....1950
Bruce W. Dickerson.....1951

The Kenneth Allen Award

From 1943 through 1948, meritorious personal service to the Member Associations of the Federation was recognized by the Kenneth Allen Award. The award was retired in 1948.

Recipients of this award have been:

1943

Harry Thornton Calvert (ISP)
Edward F. Eldridge (Mich.)
John Kurtz Hoskins (Fed.)
Fred Merryfield (Pac. N.W.)
Edward P. Molitor (N.J.)
Robert S. Phillips (N.C.)
Alfred Henry Weiters (Iowa)
William Homer Wisely (Cen. St.)

1944

Albert Edward Berry (Can.)
Van Porter Enloe (Ga.)
Albert Legrand Genter (Md.-Del.)
F. Wellington Gilcreas (New Eng.)
Charles A. Holmquist (N.Y.)
Dana Ewart Kepner (Rocky Mtn.)
Leon Benedict Reynolds (Calif.)
Wilson Waldo Towne (Dak.)

1945

Howard Eugene Moses (Pa.)
George S. Russell (Mo.)
Dario Travaini (Ariz.)
Frederick Holman Waring (Ohio)
Joe Williamson, Jr. (Fla.)
Murray Alderson Wilson (Kans.)

1946

E. J. M. Berg (Texas)
Frank E. DeMartini (Fed.)
John R. Downes (N.J.)
Thomas J. Doyle (Mich.)
John Henry Garner (ISP)
Harold Benedict Gotaas (N.C.)
William P. Hughes (Pac. N.W.)
Theodore R. Lovell (Iowa)
George W. Martin (Cen. St.)

1947

William T. Knowlton (Calif.)
Floyd W. Pinney (Dak.)
Gilbert R. Frith (Ga.)
Clarence E. Keefer (Md.-Del.)
Stuart E. Coburn (New Eng.)
Wellington Donaldson (N.Y.)
Henry J. Darcey (Okla.)
Carroll H. Coberly (Rocky Mtn.)
William Storrie (Can.)
William Merriam Cobleigh (Mont.)

1948

George W. Marx (Ariz.)
David Bryon Lee (Fla.)
William Q. Kehr (Mo.)
F. Dean Stewart (Ohio)
Francis deSales Friel (Pa.)

The Arthur Sidney Bedell Award

Established in 1948, the Arthur Sidney Bedell Award acknowledges extraordinary personal service to the Member Associations of the Federation. Each Member Association is privileged once in every three years to name one of its members to receive the award, which may be earned by organizational leadership, administrative service, membership activity, stimulation of technical functions, or similar participation. The award is named for the second President of the Federation, who exemplified its purpose by his long devotion and contribution to the affairs of the New York State Sewage Works Association.

Past recipients follow:

1949

Harry P. Croft (N.J.)
Victor Marcus Ehlers (Texas)
R. Paul Farrell (Ky.-Tenn.)
Carl Edwin Green (Pac. N. W.)
Frederick Leon McDonald (Ark.)
William Thomas Lockett (ISP)
William McKinney Piatt (N.C.)
Walter Asa Sperry (Cen. St.)
Harold Warner Streeter (Fed.)
John L. Strelow (Iowa)

1950

Leland Bradney (Dak.)
John Chester Brigham (N.Y.)
Herbert B. Foote (Mont.)
L. L. Hedgepeth (Va.)
Theodore J. Lafreniere (Can.)
Robert G. McCall (W. Va.)
Edward Alexander Reinke (Calif.)
Frank S. Taylor (Okla.)
LeRoy Winfield Van Kleeck (New Eng.)
William Hugh Weir (Ga.)
Leonard Oliver Williams, Jr. (Rocky Mtn.)
Abel Wolman (Md.-Del.)

1951

Roy Binder (Kans.)
John Clinton Clark (Ala.)
John Raymund Hoffert (Pa.)
John Robertson Hoy (Fla.)
Arthur H. Niles (Ohio)
Charles Henry Trusler (ISE)
Harold W. Yost (Ariz.)
Francis M. Veatch (Mo.)

The William D. Hatfield Award

The William D. Hatfield Award recognizes outstanding annual sewage works operation reports. Following the 1946 award, the Board of Control authorized identical awards for outstanding annual reports prepared (I) for plants serving less than 10,000 population, (II) for plants serving populations of 10,000 to 100,000, and (III) for plants serving populations of more than 100,000 persons.

Recipients of this award have been:

1946

Walter M. Kunsch

1947

F. E. Peterson (I)
John R. Szymanski (II)
Warren H. Sleeger and George J. Schroepfer (III)

1948

F. E. Peterson (I)*
Thomas T. Hay (II)
Kerwin L. Mick (III)

1949

Russell D. Craun (I)
George W. Martin (II)
Thomas T. Hay (II)*

1950

William L. Edwards (I)
Walter A. Sperry (II)
John R. Szymanski (II)*
John W. Johnson (III)

1951

William L. Edwards (I)*
J. E. Meers (II)
John R. Szymanski (II)*
George H. Craemer (III)
Kerwin L. Mick (III)*

Membership Prizes

Prizes for membership activity in its various Member Associations have been awarded by the Federation since 1943. The following Member Associations have received these prizes:

Federal Sewage Research Assn. and Central States Sewage Works Assn. 1943
Missouri Water and Sewerage Conf. and Central States Sewage Works Assn. 1944
Arizona Sewage and Water Works Assn. and Canadian Institute on Sewage and Sanitation 1945
Oklahoma Water and Sewage Conf. and Canadian Institute on Sewage and Sanitation 1946
Institute of Sewage Purification (Eng.) and Arkansas Water and Sewage Conference 1947
Pennsylvania Sewage and Industrial Wastes Association and West Virginia Sewage and Industrial Wastes Association 1948
Ohio Sewage and Industrial Wastes Treatment Conference and Alabama Water and Sewage Association 1949

* Previous winner.

Ohio Sewage and Industrial Wastes Treatment Conference and Sewage Works Section, Louisiana Conference on Water Supply and Sewerage.....1950
Institution of Sanitary Engineers (England) and Michigan Sewage and Industrial Wastes Association.....1951

The Quarter Century Operators' Club

The Quarter Century Operators' Club is an informal group comprising Active or Corporate Members of any Member Association who had been engaged in sewage treatment works operation, on a full-time resident basis, twenty-five years prior to the date of their admission into the Club. The Club was created in 1941 under the sponsorship of Frank Woodbury Jones, who serves as its registrar. The roster:

*Charles C. Agar	Arnold H. Goodman	Arthur H. Niles
*Reuben A. Anderson	William P. Gyatt	John R. Palmer
Harry M. Beaumont	Wm. C. Hamm	Wm. M. Piatt
George C. Behnke	George I. Hanson	Wm. A. Ryan
Julius W. Bugbee	William D. Hatfield	Theodore C. Schaetzle
Raymond G. Case	*Charles C. Hommon	Glenn Searls
E. Sherman Chase	Frank W. Jones	John S. Simmerman
Stuart E. Coburn	Harry J. Krum	H. W. Streeter
Morris M. Cohn	Roy S. Lamphear	Myron W. Tatlock
Rodney E. Cook	John V. Lewis	S. L. Tolman
P. N. Daniels	George S. Long	Henry Van Der Vliet
Earl Devendorf	Winfield S. Mahlie	Edwin B. Wagner
John R. Downes	C. D. McGuire	Charles E. Wheeler, Jr.
*Almon L. Fales	*Paul Molitor, Sr.	
Harry M. Freeburn	I. H. Nevitt	

ANNUAL MEETINGS AND CONVENTIONS

Annual Meeting Number	*Location*	*Date*
1	Chicago, Illinois†	October 16, 1928
2	New York, New York†	January 18, 1929
3	New York, New York†	January 14, 1930
4	New York, New York†	January 22, 1931
5	New York, New York†	January 22, 1932
6	New York, New York†	January 19, 1933
7	New York, New York†	January 18, 1934
8	New York, New York†	January 18, 1935
9	New York, New York†	January 16, 1936
10	New York, New York†	January 22, 1937
11	New York, New York†	January 21, 1938
12	New York, New York†	January 20, 1939
13	New York, New York†	January 18, 1940
	Chicago, Illinois‡	October 3–5, 1940
14	New York, New York†	January 15, 1941
	New York, New York‡	October 9–11, 1941
15	Cleveland, Ohio§	October 22–24, 1942
16	Chicago, Illinois§	October 21–23, 1943
17	Pittsburgh, Pa.§	October 12–14, 1944

* Deceased.
† Annual business meeting of Board of Control.
‡ Convention of membership-at-large.
§ Annual business meeting of Board of Control and convention of membership-at-large.

Annual Meeting Number	*Location*	*Date*
18	Chicago, Illinois†	October 17–18, 1945
19	Toronto, Ont., Can.§	October 7–9, 1946
20	Philadelphia, Pa.†	October 10, 1947
	San Francisco, Calif.‡	July 21–24, 1947
21	Detroit, Mich.§	October 18–21, 1948
22	Boston, Mass.§	October 17–20, 1949
23	Washington, D. C.§	October 9–12, 1950
24	St. Paul, Minn.§	October 8–11, 1951

DIRECTORY OF COMMITTEES

1951–52

Constitutional Committees

(*See Article VI of By-laws*)

EXECUTIVE COMMITTEE OF THE BOARD OF CONTROL

Earnest Boyce, *Chairman*

E. Sherman Chase
R. N. Clark
R. E. Fuhrman
R. H. Gould
H. D. Lyon
R. S. Rankin

PUBLICATIONS COMMITTEE

The Publications Committee arranges the technical programs for the annual conventions of the Federation and has general supervision of all publications of the Federation.

F. W. Gilcreas, *Chairman*
Rolf Eliassen, *Vice-Chairman*

L. L. Hedgepeth
B. M. McDill
F. W. Mohlman
W. H. Wisely

ORGANIZATION COMMITTEE

The Organization Committee examines and reports to the Board on applications for membership in the Federation and endeavors to encourage the formation of new regional associations or conferences eligible for membership.

Harold W. Streeter, *Chairman*

Edwin B. Cobb
Seth G. Hess

SEWAGE AND INDUSTRIAL WASTES PRACTICE COMMITTEE

The Sewage and Industrial Wastes Practice Committee reviews and directs for publication any resolution, report, or publication which establishes professional or technical standards in the name of the Federation. The following Manuals of Practice have been published under the direction of the committee:

No. 1—Occupational Hazards in Sewage Works
No. 2—Utilization of Sewage Sludge as Fertilizer
No. 3—Municipal Sewer Ordinances
No. 4—Chlorination of Sewage and Industrial Wastes

† Annual business meeting of Board of Control.
‡ Convention of membership-at-large.
§ Annual business meeting of Board of Control and convention of membership-at-large.

Morris M. Cohn, *Chairman*
D. E. Bloodgood, *Vice-Chairman*

Norval E. Anderson	C. E. Keefer	Langdon Pearse
E. B. Cobb	C. W. Klassen	Willem Rudolfs
G. P. Edwards	Kerwin L. Mick	L. W. Van Kleeck
F. W. Gilcreas	F. W. Mohlman	F. M. Veatch
K. V. Hill	A. H. Niles	W. H. Wisely

Subcommittee on Air Diffusion

This subcommittee of the Sewage and Industrial Wastes Practice Committee has been charged with the duty of producing a Manual of Practice on "Air Diffusion in Sewage Treatment." The manual is now in press.

Norval E. Anderson, *Chairman*

A. J. Beck	W. F. Schade
G. P. Edwards	C. B. Townend
C. T. Mickle	J. J. Wirts

Subcommittee on Sewer Maintenance

This subcommittee of the Sewage and Industrial Wastes Practice Committee has been directed to develop a Manual of Practice on "Maintenance of Sewers and Appurtenant Structures." The first draft of the manual is in preparation.

Chairman (To be appointed)

John H. Brooks, Jr.	Thos. B. Garry	Roy E. Phillips
W. H. Brown, Jr.	B. H. Grout	Richard Pomeroy
G. E. Finck	Grant Olewiler	Robert P. Shea
Henry Fitch	R. L. Patterson	Forest Weber

Subcommittee on Standardization of Units

This subcommittee of the Sewage and Industrial Wastes Practice Committee has been assigned to develop an approved schedule of units to be used in the reporting of plant operation and laboratory data. A committee of about forty members is at work.

Willem Rudolfs, *Chairman*

Subcommittee on Trickling Filters

This subcommittee of the Sewage and Industrial Wastes Practice Committee is engaged in the development of a Manual of Practice to be entitled "Trickling Filters—Their Characteristics and Loadings."

Kenneth V. Hill, *Chairman*

B. F. Hatch	Wm. E. Stanley
W. S. Mahlie	

Subcommittee on Sewage Works Accounting

This subcommittee was created in 1946 for the purpose of developing a Manual of Practice on accounting procedures for municipal sewage works functions. Mimeographed copies of the manual in tentative form were made available for purchase in April, 1949.

F. M. Veatch, *Chairman*

G. J. Beiswanger	K. K. Wallace
Alfred A. Estrada	S. I. Zack
E. A. Farmer	

Subcommittee on Paints and Protective Coatings

This subcommittee has the function of assembling experience and data on paints and protective coatings used in sewage works, to be presented with recommendations in the form of a manual. The subcommittee was created in 1946 and the first draft of the manual is now under review.

Kerwin L. Mick, *Chairman*

Virgil Anderson
J. W. Johnson
L. S. Kraus
W. T. McClenahan
F. W. Pinney
Walter A. Sperry
M. L. Robins

Research Committee

The Research Committee has the function of stimulating research work among the various Member Associations, and of cooperating with other organizations in the promotion of research.

Willem Rudolfs, *Chairman*
H. Heukelekian, *Vice-Chairman*

D. E. Bloodgood
G. P. Edwards
M. B. Ettinger
H. A. Faber
H. W. Gehm
P. D. Haney
R. D. Hoak
P. W. Kabler
Max Katz
C. E. Keefer
R. M. Manganelli
P. H. McGauhey
H. J. Miles
F. W. Mohlman
W. Allen Moore
H. E. Orford
G. A. Rohlich
C. C. Ruchhoft
N. H. Sanborn
L. R. Setter
H. A. Trebler
L. W. Van Kleeck

Subcommittee on Toxicity of Industrial Wastes

This subcommittee of the Research Committee is functioning in three sections:

Section I. Critical review of literature; Willem Rudolfs, *Chairman*, C. E. Barnes, P. Doudoroff, G. P. Edwards, H. Heukelekian, F. W. Kittrell, C. E. Renn and R. F. Weston.

Section II. Development of methods for toxicity determinations on wastes; J. A. McCarthy, *Chairman*, S. E. Coburn, G. P. Edwards, H. Heukelekian, E. Hurwitz, R. S. Ingols, C. C. Ruchhoft, W. W. Sanderson, C. M. Sawyer and R. F. Weston.

Section III. Development and standardization of bio-assay methods; P. Doudoroff, *Chairman*, B. G. Anderson, G. E. Burdick, P. S. Galtsoff, W. B. Hart, R. Patrick, E. R. Strong, E. W. Surber and W. M. Van Horn.

Finance Committee

The Finance Committee develops the annual operating budget of the Federation and affords guidance to the Board of Control in financial affairs.

W. J. Orchard, *Chairman*

Earnest Boyce
R. E. Fuhrman

Special Committees

Committee on Awards

The Committee on Awards was created by the Board of Control on October 11, 1941. Functions of the committee are to advise the Board on matters of award procedures and to make recommendations as to the annual winners of the Eddy, Gascoigne, Emerson, and Industrial Wastes medals.

G. A. Rohlich, *Chairman*

T. R. Hazeltine Harold A. Thomas

Honorary Membership Committee

Authorized by the Board of Control on October 24, 1942, this committee comprises the President and four latest, living Past Presidents with the senior Past President as chairman. The committee reviews nominations for election to the grade of Honorary Member and makes recommendations to the Board on such nominations.

G. S. Russell, *Chairman*

Earnest Boyce R. E. Fuhrman
V. M. Ehlers A. H. Niles

Operator's Qualifications Committee

Authorized by the Board of Control on October 11, 1941, the Operator's Qualifications Committee is assigned to "establish minimal qualifications for operators of various classes of treatment works." The committee also has the duty of collecting and compiling data on present procedures in the licensing and certification of operators for reference to Member Associations.

L. W. Van Kleeck, *Chairman*

Benjamin Benas T. C. Schaetzle

Industrial Wastes Committee

The Industrial Wastes Committee was created by the Board of Control on October 23, 1943, for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial waste problems.

F. W. Mohlman, *Chairman*
R. W. Hess, *Vice-Chairman*

H. E. Babbitt H. W. Gehm H. S. Kline
R. R. Balmer W. B. Hart L. F. Oeming
D. E. Bloodgood L. L. Hedgepeth Wm. S. Wise

Nominating Committee

The special Nominating Committee was created by the Board of Control on October 9, 1946, to function in an advisory capacity to the Election Committee. The Nominating Committee is to comprise the last five living Past Presidents, with the senior Past President as chairman.

F. S. Friel, *Chairman*

V. M. Ehlers A. H. Niles
R. E. Fuhrman G. S. Russell

Quarter Century Operators' Club Committee

The special Quarter Century Operators' Club Committee was created by the Board of Control on October 9, 1946. It is the function of this Committee to establish eligibility requirements, process membership applications, maintain the roster, and supervise the activities of the Quarter Century Operators' Club.

Frank W. Jones, *Chairman*

W. P. Gyatt Harold W. Streeter

Legislative Analysis Committee

The Legislative Analysis Committee was created by the Board of Control on October 17, 1945, to study legislation pertinent to the interests of the Federation and to serve the Board in advisory capacity.

David B. Lee, *Chairman*

E. J. Cleary
C. E. Schwob
C. I. Sterling
R. L. Winget

Constitution and By-Laws Committee

The Constitution and By-laws Committee was created by the Board of Control on October 10, 1947, to review and develop recommendations for the amendment of the Constitution and By-laws of the Federation as may be deemed advisable under changing conditions.

C. A. Emerson, *Chairman*

F. S. Friel
F. W. Gilcreas
W. J. Orchard
G. S. Russell

Joint Committees With Other Associations

Joint Committee on Chlorine Supply

On October 11, 1951, the Board of Control authorized participation in the Joint Committee on Chlorine Supply with the American Water Works Association and the Conference of State Sanitary Engineers. The objective of the committee is to study problems of chlorine supply and distribution in the water and sewage fields, and to develop recommendations for their solution.

FSIWA Representatives

L. H. Enslow
L. L. Hedgepeth (Alternate)
L. F. Oeming

Committee on Standard Methods of Sewage and Industrial Wastes Analysis

Created by the Board of Control on January 22, 1931, the Committee on Standard Methods of Sewage and Industrial Wastes Analysis has functioned with similar committees of the American Water Works Association and American Public Health Association in the production of the laboratory manual *Standard Methods for the Examination of Water and Sewage*. In 1947 the Federation became a joint publisher of this book with the above associations. The committee is presently engaged in a comprehensive research project on analytical methods, which project is being financed by grants made through the National Institutes of Health.

W. D. Hatfield, *Chairman*
G. P. Edwards, *Vice-Chairman*

L. D. Betz
D. E. Bloodgood
A. M. Buswell
S. E. Coburn
Keeno Fraschina
H. Heukelekian
R. D. Hoak
E. F. Hurwitz
R. S. Ingols
J. E. Kinney
F. W. Kittrell
W. S. Mahlie
M. G. Mellon
E. W. Moore
M. Starr Nichols
Richard Pomeroy
C. C. Ruchhoft
Willem Rudolfs
W. W. Sanderson
C. N. Sawyer
G. E. Symons
R. F. Weston

WATER, SEWAGE AND INDUSTRIAL WASTES JOINT COMMITTEE ON CRITICAL MATERIALS

This joint committee was formed on December 6, 1950, with representation by the American Water Works Association, the American Public Health Association, the Water and Sewage Works Manufacturers' Association, and the Federation. The committee is engaged in the analysis of problems of materials procurement and allocation to the construction and operation of water supply and waste disposal facilities during the present national emergency. It is now cooperating closely with the Water Resources Division of the National Production Authority.

FSIWA Representatives

R. E. Fuhrman W. H. Wisely

Special Convention Committees

CONVENTION MANAGEMENT COMMITTEE

The function of this committee is to supervise details of the management of the Annual Meetings of the Federation.

W. J. Orchard, *Chairman*

R. H. Gould J. G. Stewart
R. S. Rankin W. H. Wisely

MEETING PLACE COMMITTEE

This committee reviews invitations received for the Annual Meetings of the Federation and makes recommendations to the Board of Control in regard to the time and place of such meetings.

Earnest Boyce, *Chairman*

E. Sherman Chase R. F. Orth
R. E. Fuhrman J. G. Stewart
E. M. Jones W. H. Wisely

PUBLICITY AND ATTENDANCE COMMITTEE

The function of this committee is to prepare publicity releases in connection with the Annual Meetings of the Federation and to direct the distribution of such material.

L. H. Enslow, *Chairman*

W. S. Foster W. A. Hardenbergh

Directory of Members

SUMMARY OF MEMBERSHIP

(As of December 31, 1951)

Federation Members

Honorary Members	10
Associate Members	80
Member Associations	36
Active Members	5,118
Corporate Members	120

Net Membership of Member Associations *

Member Association	Active	Honorary	Corporate	Total
Alabama	38	—	4	42
Arizona	27	—	2	29
Arkansas	52	—	—	52
California	445	1	—	446
Canadian Inst	367	—	—	367
Central States	523	3	19	545
Dakota	43	—	—	43
Federal	98	—	—	98
Florida	106	—	—	106
Georgia	36	—	—	36
Germany	34	—	—	34
Iowa	140	—	—	140
ISE (England)	22	—	—	22
ISP (England)	145	—	—	145
Kansas	55	—	1	56
Kentucky-Tennessee	97	—	4	101
Louisiana	2	—	—	2
Maryland-Delaware	59	—	—	59
Michigan	300	—	1	301
Missouri	37	—	1	38
Montana	37	—	8	45
New England	330	2	—	332
New Jersey	186	1	—	187
New York	594	1	12	607
North Carolina	93	—	—	93
Ohio	269	—	21	290
Oklahoma	34	—	—	34
Pacific Northwest	198	—	—	198
Pennsylvania	346	2	27	375
Puerto Rico	5	—	—	5
Rocky Mountain	68	—	1	69
South Carolina	16	—	1	17
Swiss	15	—	—	15
Texas	125	—	—	125
Virginia	90	—	13	103
West Virginia	86	—	5	91
Totals	5,118	10	120	5,248

* Not including Dual Members.

MEMBER ASSOCIATIONS

Alabama Water and Sewage Association—Sewage Works Section (Affiliated 1948).

Territory: State of Alabama.
President: E. E. Love; *Vice-President:* C. Hammond; *Director:* J. C. Clarke; *Treasurer:* G. H. Dunstan; *Secretary:* Alex O. Taylor, Box 69, Auburn, Ala.

Arizona Sewage and Water Works Association—Sewage Works Section (Affiliated 1928).

Territory: State of Arizona.
President: S. P. Henderson; *First Vice-President:* M. V. Ellis; *Second Vice-President:* I. F. Brown; *Director:* Harold Yost; *Secretary-Treasurer:* H. S. Jordan, c/o Sanitary Engineering Div., State Dept. of Health, Capitol Bldg., Phoenix, Ariz.

Arkansas Water and Sewage Conference—Sewage Works Section (Affiliated 1946).

Territory: State of Arkansas.
Chairman: C. A. Brown; *Vice-Chairman:* J. J. Highfill; *Director:* B. W. Dees; *Secretary-Terasurer:* Harrison Hale, Southern State College, Magnolia, Ark.

California Sewage Works Association (Affiliated 1928).

Territory: State of California.
President: H. B. Gotaas; *First Vice-President:* Arthur G. Pickett; *Second Vice-President:* Lawrence H. Cook; *Director:* K. A. Keirn; *Secretary-Treasurer:* Sam A. Weed, Rm. 315, City Hall, Oakland, Calif.

Canadian Institute on Sewage and Sanitation (Affiliated 1933).

Territory: Dominion of Canada.
President: C. S. Anderson; *Vice-President:* G. H. Baker; *Director:* William Storrie; *Secretary-Treasurer:* A. E. Berry, Ontario Dept. of Health, Parliament Buildings, Toronto, Ont., Can.

Central States Sewage and Industrial Wastes Association (Affiliated 1928).

Territory: States of Illinois, Indiana, Wisconsin and Minnesota.
President: M. L. Robins; *First Vice-President:* W. W. Mathews; *Second Vice-President:* E. Hurwitz; *Third Vice-President:* O. J. Muegge; *Director:* W. D. Hatfield; *Secretary-Treasurer:* A. Paul Troemper, c/o Illinois Sanitary Water Board, Springfield, Ill.

Dakota Water and Sewage Works Conference—Sewage Works Sections (Affiliated 1936).

North Dakota Section

Territory: State of North Dakota.
President: K. R. Johnson; *Vice-President:* E. J. Booth; *Director:* John Kleven; *Secretary-Treasurer:* Jerome H. Svore, c/o State Dept. of Health, Bismarck, N. Dak.

South Dakota Section

Territory: State of South Dakota.
President: W. Johnson; *Vice-President:* A. Hanson; *Director:* John Kleven; *Secretary-Treasurer:* Charles E. Carl, c/o State Board of Health, Div. of Sanitary Engineering, Pierre, S. Dak.

Federal Sewage Research Association (Affiliated 1930).

Territory: Federal employees wherever stationed.
President: L. B. Dworsky; *Vice-President:* R. S. Smith; *Director:* Robert N. Clark; *Secretary-Treasurer:* Wm. Davis, Federal Sewage Research Assn., Room 4218, Fed. Security Bldg., So., Washington 25, D. C.

Florida Sewage and Industrial Wastes Association (Affiliated 1941).

Territory: State of Florida.
President: John E. Kiker, Jr.; *Vice-President:* John W. Wakefield; *Director:* J. R. Hoy; *Secretary-Treasurer:* Donald P. Schiesswohl, Florida State Board of Health, P. O. Box 210, Jacksonville 1, Fla.

Georgia Water and Sewage Association—Sewage Works Section (Affiliated 1936).

Territory: State of Georgia.
President: V. D. Parrott, Jr.; *First Vice-President:* L. C. Bowen; *Second Vice-President:* S. Russell; *Director:* R. S. Ingols; *Asst. Secretary-Treasurer:* I. C. Kelley; *Secretary-Treasurer:* A. T. Storey, 1210 Hemphill Ave., N. W., Atlanta, Ga.

German Sewage Technologists Association (Affiliated 1950).

Territory: Western Germany.
President: Max Prüss; *Vice-President:* Franz Schreier; *Director:* Karl Imhoff; *Secretary-Treasurer:* Wilhelm Bucksteeg, Schliessfach 1112, Ruhrverband, Essen, Germany.

Institute of Sewage Purification—England (Affiliated 1932).

Territory: British Empire.
President: John H. Garner; *Director:* Martin Lovett; *Honorary Secretary:* W. F. Freeborn; *FSIWA Contact Member:* Martin Lovett, 206 Bradford, Wakefield, Yorkshire, Eng.

Institution of Sanitary Engineers—England (Affiliated 1932).

Territory: British Empire.
President: S. Brassey-Edwards; *Vice-President:* W. E. Fretwell; *Director:* C. B. Townend; *Treasurer:* J. W. Hammond; *Secretary:* Ernest V. Balsom, 118 Victoria St., Westminster, S. W. 1, London, England.

Iowa Sewage Works Association (Affiliated 1928).

Territory: State of Iowa.
President: M. L. Wickersheim; *Vice-President:* J. L. Strelow; *Director:* P. J. Houser; *Secretary-Treasurer:* Leo Holtcamp, P. O. Box 310; Webster City, Ia.

Kansas Sewage Works Association (Affiliated 1935).

Territory: State of Kansas.
Chairman: L. Talbot; *Vice-Chairman:* H. L. Ramage; *Director:* G. E. Mau; *Secretary-Treasurer:* D. F. Metzler, c/o State Board of Health, Marvin Hall, University of Kansas, Lawrence, Kans.

Kentucky-Tennessee Industrial Wastes and Sewage Works Association (Affiliated 1946).

Territory: States of Kentucky and Tennessee.
Chairman: W. J. Eldridge; *Vice-Chairman:* H. D. Regan; *Director:* Maurice L. Miller; *Secretary-Treasurer:* R. P. Farrell, 420 Sixth Ave., N. Nashville, Tenn.

Louisiana Conference on Water Supply and Sewerage—Sewage Works Section (Affiliated 1949).

Territory: State of Louisiana.
Chairman: N. Lorio; *Vice-Chairman:* L. J. Dore; *Director:* S. S. Crawford; *Secretary-Treasurer:* G. H. West, Lake Charles, La.

Maryland-Delaware Water and Sewerage Association—Sewage Works Section (Affiliated 1928).

Territory: States of Maryland and Delaware.
President: L. E. McClung; *First Vice-President:* V. W. Faivre; *Second Vice-President:* R. H. Ritter; *Director:* W. M. Bingley; *Secretary-Treasurer:* W. M. Bingley, 2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Association (Affiliated 1930).

Territory: State of Michigan.
President: C. W. Hathaway; *First Vice-President:* W. E. Smith; *Second Vice-President:* R. D. Craun; *Director:* L. F. Oeming; *Secretary-Treasurer:* D. M. Pierce, Michigan Dept. of Health, Room 334, Administration Bldg., Lansing 4, Mich.

Missouri Water and Sewerage Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Missouri.
Chairman: Raymond Bishop; *Vice-Chairman:* William B. Schworm; *Director:* L. J. Lukrofka; *Secretary-Treasurer:* Warren A. Kramer, c/o State Office Bldg., Sixth Fl., Jefferson City, Mo.

Montana Sewage Works Association (Affiliated 1944).

Territory: State of Montana.
Chairman: R. Preator; *Vice-Chairman:* S. B. Ward; *Director:* Earl Eby; *Secretary-Treasurer:* H. B. Foote, Div. of Sanitary Eng., State Board of Health, Helena, Mont.

New England Sewage and Industrial Wastes Association (Affiliated 1929).

Territory: States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island.
President: E. Sherman Chase; *First Vice- President:* E. L. Bond; *Second Vice-President:* C. G. Hamman; *Director:* W. H. Brown, Jr.; *Secretary-Treasurer:* Walter H. Merrill, c/o State Dept. of Health, 511A State House, Boston, Mass.

New Jersey Sewage and Industrial Wastes Association (Affiliated 1942).

Territory: State of New Jersey.
President: John Struss; *First Vice-President:* Sol Seid; *Second Vice-President:* Paul Molitor, Jr.; *Director:* Henry Van Der Vliet; *Secretary-Treasurer:* M. S. Kachorsky, P. O. Box 766, Manville, N. J.

New York Sewage and Industrial Wastes Association (Affiliated 1930).

Territory: State of New York.
President: J. M. MacCrea; *Vice-President:* W. R. Schreiner; *Director:* W. H. Larkin; *Treasurer:* J. C. Brigham; *Secretary:* R. C. Sweeney, c/o State Dept. of Health, 21 N. Broadway, White Plains, N. Y.

North Carolina Sewage and Industrial Waste Association (Affiliated 1929).

Territory: State of North Carolina.
Chairman: H. F. Davis; *Vice-Chairman:* J. E. Greenlee; *Director:* R. S. Phillips; *Secretary-Treasurer:* E. C. Hubbard, North Carolina State Board of Health, Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conference (Affiliated 1932).

Territory: State of Ohio.
Chairman: Walter E. Gerdel; *First Vice-Chairman:* Donald G. Stevens; *Second Vice-Chairman:* W. D. Sheets; *Director:* T. C. Schaetzle; *Secretary-Treasurer:* John E. Richards, 301 Ohio Depts. Bldg., Columbus 15, Ohio.

Oklahoma Water, Sewage and Industrial Waste Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Oklahoma.
President: F. E. Wingfield; *Vice-President:* W. J. Bishop; *Director:* J. T. Sprague; *Secretary-Treasurer:* H. J. Darcey, State Dept. of Health, Oklahoma City 5, Okla.

Pacific Northwest Sewage Works Association (Affiliated 1933).

Territory: States of Washington, Oregon, and Idaho.
President: W. W. Tinniswood; *Vice-President:* C. M. Everts, Jr.; *Director:* W. P. Hughes; *Secretary-Treasurer:* R. O. Sylvester, c/o Div. of Sanitary Engineering, More Hall, University of Washington, Seattle 5, Wash.

Pennsylvania Sewage and Industrial Wastes Association (Affiliated 1928).

Territory: State of Pennsylvania.
President: R. M. Bolenius; *First Vice-President:* R. F. Weston; *Second Vice-President:* T. R. Haseltine; *Director:* C. H. Young; *Secretary-Treasurer:* B. S. Bush, c/o Pennsylvania Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Association (Affiliated 1947).

Territory: Puerto Rico.
President: Manuel Vinas Sarba; *Vice-President:* W. C. Hill; *Director:* Felipe Bosch; *Secretary-Treasurer:* Alvah R. Pierce, c/o Puerto Rico Aqueduct & Sewer Service, Box 2832, San Juan 12, P. R.

Rocky Mountain Sewage Works Association (Affiliated 1947).

Territory: States of Wyoming, Colorado, and New Mexico.
President: R. Sherrard; *Vice-President:* C. Coberly; *Director:* C. G. Caldwell; *Secretary-Treasurer:* C. E. Harness, City Engineer, 272 City and County Bldg., Denver, Colo.

South Carolina Water and Sewage Works Association—Sewage Works Section (Affiliated 1949).

Territory: State of South Carolina.
President: T. E. Robertson; *Vice-President:* Albert J. Lucas; *Director:* George A. Rhame; *Secretary-Treasurer:* W. T. Linton, Wade Hampton Bldg., Columbia, S. C.

Swiss Association of Water and Sewage Professionals (Affiliated 1947).

Territory: Switzerland.
President: A. Kropf; *Vice-President:* H. Bachoffner; *Director:* Walter Dardel; *Secretary:* Edward Holinger, Spitzackerstrasse 17, Liestal, Switzerland.

Texas Water and Sewage Works Association—Sewage and Industrial Wastes Section (Affiliated 1928).

Territory: State of Texas.
Chairman: C. H. Connell; *Vice-Chairman:* A. H. Ulrich; *Director:* E. W. Steel; *Secretary:* V. M. Ehlers, 501 W. 33 St., Austin, Tex.; *Assistant Secretary and Treasurer:* Mrs. Earl V. Goodwin.

Virginia Industrial Wastes and Sewage Works Association (Affiliated 1947).

Territory: State of Virginia.
President: Stuart Crawford; *Vice-President:* S. H. Reaves; *Director:* E. C. Meredith; *Secretary-Treasurer:* G. R. Talcott, 415 West Franklin St., Richmond 20, Va.

West Virginia Sewage and Industrial Wastes Association (Affiliated 1947).

Territory: State of West Viriginia.
President: H. W. Speiden; *First Vice-President:* A. R. Todd; *Second Vice-President:* W. D. Kelley; *Director:* H. D. Lyon; *Secretary-Treasurer:* G. O. Fortney, State Department of Health, Charleston, W. Va.

HONORARY MEMBERS

Bugbee, Julius W. (1942), 246 Lowell Ave., Providence 9, R. I.

DeBerard, Wilford Willis (1950), City Engr., Bur. of Eng., Dept. of Pub. Works, 402 City Hall, Chicago 2, Ill.

Emerson, Charles A. (1941), Cons. Engr., Havens & Emerson, Woolworth Bldg., New York 7, N. Y.

Gilcreas, F. Wellington (1948), Asst. Dir., Div. of Lab. & Research, State Dept. of Health, New Scotland Ave., Albany 1, N. Y.

Hyde, Charles Gilman (1943), Cons. Engr., 2495 Shattuck Ave., Berkeley 4, Calif.

Mohlman, Dr. Floyd W. (1944), Dir., Div. of Lab., Sanitary Dist. of Chicago, 910 S. Michigan Ave., Chicago 5, Ill.

Moses, Howard E. (1943), Chief Sanitary Engr., State Dept. of Health, 1522 N. Second St., Harrisburg, Pa.

Orchard, William J. (1946), Gen. Mgr., Wallace & Tiernan Co., Inc., Newark 1, N. J.

Pearse, Langdon (1942), Sanitary Engr., Sanitary Dist. of Chicago, 910 S. Michigan Ave., Chicago 5, Ill.

Rudolfs, Dr. Willem (1945), Chief, Dept. of Sanitation, Agr. Experiment Sta., Short Course B'dg., New Brunswick, N. J.

ASSOCIATE MEMBERS

Albert Pipe Supply Co., Inc., Berry & North 13th St., Brooklyn 11, N. Y., Rep. J. J. Dougherty.

Aluminum Co. of America, New Kensington, Pa., Rep. R. C. Kasser.

American Cast Iron Pipe Co., Birmingham, Ala., Rep. E. L. Gilder.

American City Magazine, 470 Fourth Ave., New York, N. Y., Rep. Edgar J. Buttenheim, Pres.

American Concrete Pipe Assn., 228 N. LaSalle St., Suite 1033, Chicago 1, Ill., Rep. Howard F. Peckworth, Managing Dir.

American Lumber & Treating Co., 332 S. Michigan Ave., Chicago 4, Ill., Rep. J. E. L. McCall, Adv. Mgr.

American Well Works, Aurora, Ill., Rep. L. H. Kramer, Exec. Vice Pres.

Armco Drainage & Metal Products, Inc. (Armco Steel Corp.), Middletown, Ohio, Rep. W. H. Spindler, Pub. Mgr.

Automatic Control Co., 1005 University Ave., St. Paul 4, Minn., Rep. J. S. Williams.

Bristol Co., Waterbury, Conn., Rep. F. W. Borchers, Asst. Sales Mgr.

Builders-Providence, Inc., Div. of Builders Iron Foundry, P. O. Box 1342, Providence, R. I., Rep. W. W. Adams, Asst. Sales Mgr.

Carter, Ralph B., Co., 192 Atlantic St., Hackensack, N. J., Rep. J. J. Horgan.

Chain Belt Co., Milwaukee, Wis., Rep. W. B. Marshall.

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Zeller, P. J. Alwin, Research Assoc., Eng. Exp. Sta., Tex. A & M College, P. O. Box 5664, College Station, Tex. (Tex.)

Ziegler, Alvin, Pa. Hide Co., Inc., 917 Middle St., Scranton, Pa. (Pa.)

Zigerli, P., Cons. Engr., Forchstr. 67, Zurich, Switz. (Swiss)

Zimmer, Frank J., Supt., Water & Sewage Tr. Plants, Farmington, Mo. (Mo.)

Zimmer, Henry A., Rep., Walker Process Equip., Inc., P. O. Box 192, Moline, Ill. (Ia.)

Zimmerman, Leslie L., Supt., Dept. of Water & Sewerage, 15 N. Pearl St., Covington, Ohio (Ohio)

Zimmerman, Willard W., Supt., Sewage Disp. Works, Box 53, Cassopolis, Mich. (Mich.)

Zink, Dipl-Ing. Otto, Breitscheidstr. 93, Stuttgart, Germany (Germany)

Zink, Ray E., Hotpoint, Inc., 5600 W. Taylor St., Chicago 44, Ill. (Cen. St.)

Zinn, Clyde, Supt., Water & Light Plant, Hope, Ark. (Ark.)

Zinsmeister, H. F., Engr., Wallace & Tiernan Co., Inc., 230 E. Ohio St., Indianapolis, Ind. (Cen. St.)

Zoeller, August, Asst. Plant Opr., Sewage Tr. Plant, 4 Colonial Ave., Merrick, N. Y. (N.Y.)

Zoellner, Robert W., Armco Drainage & Metal Products, Inc., Seventh & Parker Sts., Berkeley 10, Calif. (Calif.)

Zollner, Frederick D., Dist. Sanitary Engr., State Dept. of Health, 218 E. Main St., Batavia, N. Y. (N.Y.)

Zorn, Ray H., Mgr., Power Equip. Co., Oak Harbor, Ohio (Ohio)

Zubkoff, Seymour, Civil Engr., Elson T. Killam Assoc., 529 Millburn Ave., Short Hills, N. J. (N.Y.)

Zuest, William H., Plant Engr., Diehl Mfg. Co., Finderne Plant, Somerville, N. J. (N.J.)

Zumstein, Harold F., Civil Engr., Farrington Co., 5397 Seneca Ave., Detroit 13, Mich. (Mich.)

Zydallas, Charles, Asst. Supt., Sewage Tr. Plant, 250 Pope St., Manville, N. J. (N.J.)

2 — 80'-0" diameter oxidators as installed at sewage treatment plant at Santa Barbara, California. 2 — P.F.T. 65'-0" diameter floating cover digesters in background. Koebig and Koebig, consulting engineers.

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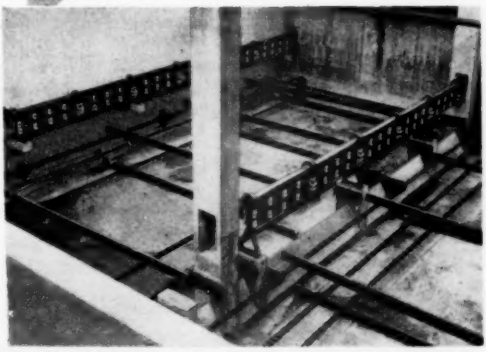
For CIRCULAR sedimentation tank P.F.T. offers the Oxidator. This unit, developed by Process Engineers, Inc. of California, combines pre-aeration and improved sedimentation in a single structure. The untreated waste enters the center pre-aeration chamber wherein it is aerated, mixed, and flocculated along with returned sludge solids. The aerated, flocculated material passes uniformly under the separating baffle into the upflow sedimentation compartment.

For RECTANGULAR sedimentation tanks P.F.T. offers pre-aeration in the inlet portion of the sedimentation tank structure, again combining the economies and advantages of complete conditioning of the waste by aeration and flocculation and improved sedimentation in a single structure. Upflow sedimentation with effective inlet distribution into the sedimentation compartment is a feature of this



SEND FOR YOUR COPY OF BULLETIN No. 106 P. F. T. OXIDATORS

P.F.T. vertical plate holder pre-aeration equipment in inlet portion of primary sedimentation tanks at Stockton, California sewage treatment plant. Clyde C. Kennedy, consulting engineer.

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Proceedings of Member Associations

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Fifth Annual Conference of the West Virginia Sewage and Industrial Wastes Association was held at the Daniel Boone Hotel, Charleston, W. Va., October 3–4, 1951. Registration totaled 192 members and guests.

The technical program for the morning of October 3 included the following papers:

"Recent Developments in Sewage Treatment," by A. H. Niles, past president, FSIWA.

"Catalytic Oxidation," by R. V. Green, assistant technical superintendent, Polychemical Department, E. I. du Pont de Nemours Company, Belle.

"Plans and Activities of the Potomac River Commission—Its Land Committee," by E. R. Cotton, director, Interstate Commission on the Potomac River Basin, Washington, D. C.

The afternoon session was devoted to papers concerning sewage and industrial wastes treatment and stream regulation practices, as follows:

"Modern Sewage Treatment Plants in West Virginia," by Robert R. Anderson, design engineer, Settle Engineers, Inc., Charleston.

"Stream Regulation Practices of Hydroelectric Facilities," by H. E. McCormack, superintendent of systems operations, Appalachian Electric Power Company, Roanoke, Va.

"Coal Washing—Treatment of Wastes," by G. A. Reilly, supervising engineer, and J. F. Maurice, engineer, Red Jacket Coal Corporation, Red Jacket.

"Stream Pollution Abatement at Willow Island" (In three parts):

I. "Present Treatment," by John F. Vogler, sanitary engineer, Willow Island Plant, Calco Chemical Division, American Cyanamid Company.

II. "Additional Loading from Antibiotics," by J. M. Brown, sanitary engineer, Pearl River Plant, Lederle Laboratory Division, American Cyanamid Company.

III. "Plans for Additional Treatment," by Guy E. Griffen, sanitary engineer, Central Engineering Department, American Cyanamid Company.

The morning of the second day was devoted to a joint program with the West Virginia Section, American Water Works Association. This program, which consisted of a movie and technical papers of interest to both groups, included the following presentations:

"West Virginia and Its Natural Resources," a movie by the West Virginia Industrial and Publicity Commission.

"Fundamental Studies of Taste and Odor in Water," by Frank M. Middleton, chemist, Environmental Health Center, U. S. Public Health Service, Cincinnati, Ohio.

"Biological Investigations in Water Pollution," by W. M. Ingram, biologist, Ohio and Tennessee Drainage Basins, U. S. Public Health Service, Cincinnati, Ohio.

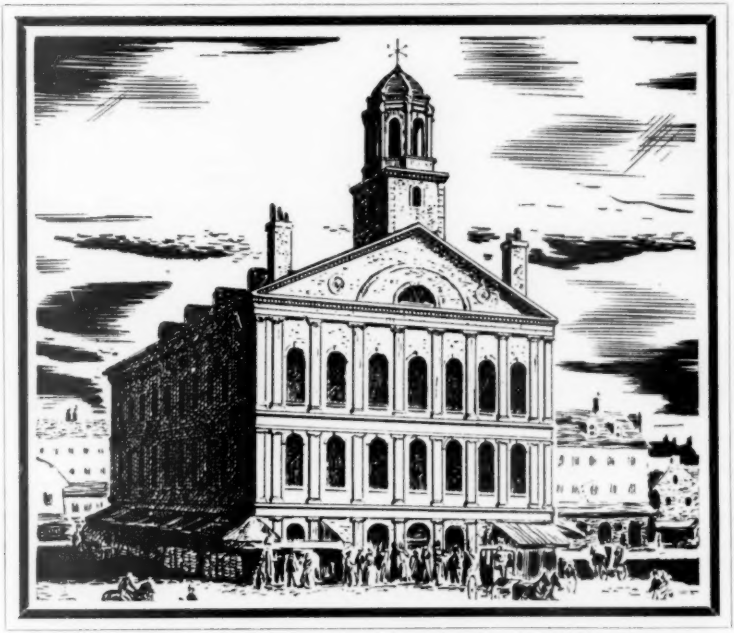
"Summary and Significance of Water Commission Court Cases," by T. J. Gillooly, Assistant Attorney General, State of West Virginia, Charleston.

The business meeting was also held on October 4, after the morning technical session. Officers elected to serve during the coming year were:

President: H. W. Speiden, Morgantown, W. Va.

1st Vice-President: A. R. Todd, Wheeling, W. Va.

(*Continued on page 112a*)



Boston's Faneuil Hall, popularly called "The Cradle of Liberty", as it looked 100 years ago

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2nd Vice-President: W. D. Kelley, Charleston, W. Va.
FSIWA Director: H. D. Lyon, Louisville, Ky.
Secretary-Treasurer: G. O. Fortney, Charleston, W. Va.

The Annual Joint Banquet was held the evening of October 4 in conjunction with the West Virginia Section, American Water Works Association.

G. O. FORTNEY,
Secretary-Treasurer

NEW ENGLAND SEWAGE WORKS ASSOCIATION

The Twenty-Third Annual Fall Meeting of the New England Sewage Works Association was held at The Sheraton-Biltmore, Providence, R. I., November 6–7, 1951. The total registration was 161 members and guests.

The morning program of November 6 opened with the annual business meeting, at which the following officers were elected for 1952:

President: E. S. Chase, Boston, Mass.
1st Vice-President: E. L. Bond, Greenfield, Mass.
2nd Vice-President: C. G. Hammann, Providence, R. I.
Secretary-Treasurer: W. E. Merrill, Boston, Mass.
Ass't. Sec.-Treas.: S. M. Hurley, Jr., Providence, R. I.

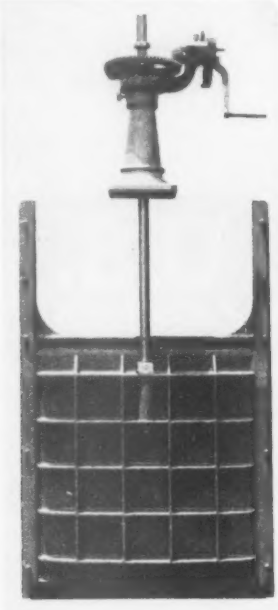
Also, it was voted that, effective January 1, 1952, the name of the Association should be changed to New England Sewage and Industrial Wastes Association.

Technical papers presented at the morning session were:

"Rhode Island's Stream Pollution Control Program," by Walter J. Shea, Rhode Island Department of Health.

"Phase I—Blackstone Valley Sewer District Project," by Clarence V.

(*Continued on page 114a*)



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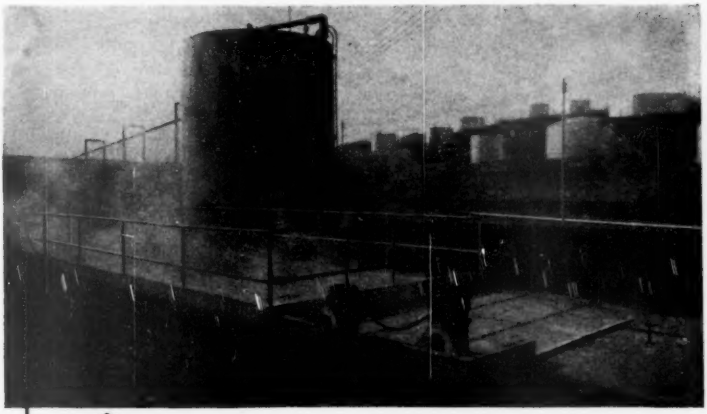
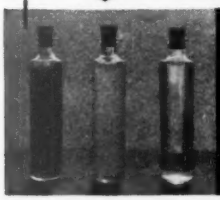


Dougherty Refinery, Chemical Oil Precipitation Plant.

Inset: Raw, First Stage and Final Effluent.



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Hickey, Blackstone Valley Sewer District.

"Cranston Sewage Treatment Plant":

(a) "Design Features," by Ralph W. Horne, partner, Fay, Spofford & Thorndike, Boston, Mass.

(b) "Operational Features," by Walter C. Anderson, superintendent.

"New Warren Sewage Treatment Plant":

(a) "Design and Construction," by Allen J. Burdoin, Metcalf & Eddy, Boston.

(b) "First Year's Operation," by J. William Crowley, superintendent.

"East Providence Sewerage," by Arthur D. Weston, consultant, Charles A. Maguire and Associates.

The afternoon program included the following papers:

"Some New Aspects of Phosphates in Relation to Lake Fertilization," by Clair N. Sawyer, Massachusetts Institute of Technology.

"Nitrogen and Phosphorus Utilization in the High-Rate Trickling Filter," by Harold D. Kilgore, Jr., Anderson-Nichols & Co., Boston.

The afternoon program closed with a symposium on "High-Rate Trickling Filters in New England." Frank L. Flood, Metcalf & Eddy, outlined the history and development of these filters. This was followed by operators' discussions and the symposium closed with a summary and predictions for the future by J. Henry L. Giles, Connecticut State Department of Health.

The afternoon program closed with a social hour sponsored by the Water and Sewage Works Manufacturers Association.

The second day's program opened with a well-attended Association breakfast. Following breakfast, concurrent technical meetings were held on industrial wastes and sewage plant operation.

At the industrial wastes session three prepared papers were presented as follows:

"Studies of Wool Scouring Wastes," by Harold H. Webber, Lowell Textile Institute Research Foundation.

"Use of Calcium Chloride for Industrial Wastes Treatment," by J. A. McCarthy, Lawrence (Mass.) Experiment Station.

"Treatment of Cotton-Finishing Wastes at the Sayles Finishing Plants Inc., Saylesville, R. I.," by George G. Bogren, partner, Weston and Sampson, Boston.

The sewage plant operators' meeting was devoted primarily to open discussion on "What's Wrong With My Plant?" Following luncheon, visitations were made to the Blackstone Valley, Cranston, East Providence, and Warren sewage treatment plants.

WALTER E. MERRILL,
Secretary-Treasurer

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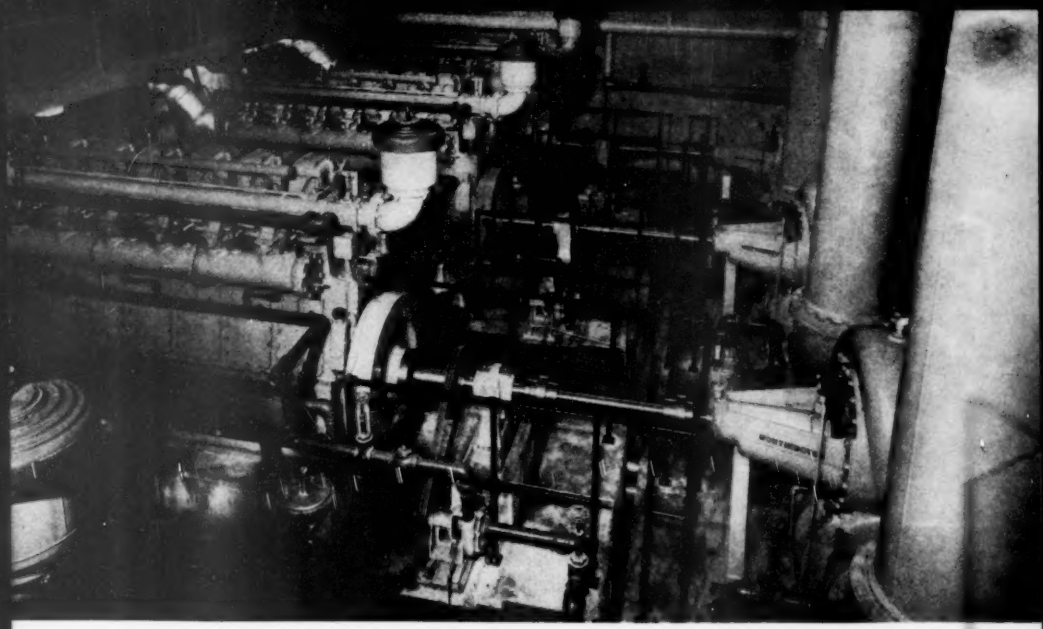

FOUR 20-MGD CENTRIFUGAL PUMPS (right) pump raw sewage into Oklahoma City's Southside Sewage Treatment Plant. Worthington Sewage Gas Engines (left) drive pumps. Installation uses three other such pumps for recirculation, also driven by Worthington engines.

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An outstanding job in every way. That's what ey're all saying about the new Southside Sew- e Treatment Plant at Oklahoma City.

Seven giant Worthington 20-mgd centrifugal mps used for pumping raw sewage and recircu- tion are driven by Worthington gas-engines at are fueled by methane gas from raw sewage.

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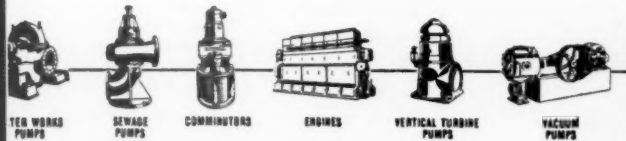

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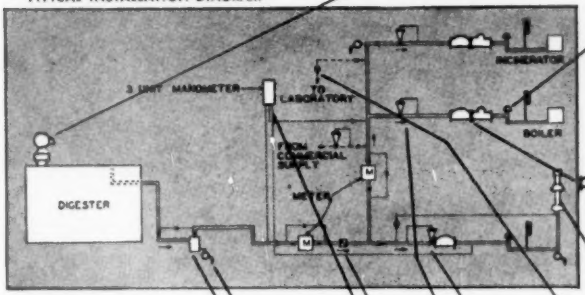
TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70—Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

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"VAREC" Flame Check—Fig. 51A or 52A—Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 or 387—Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve—Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer—Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

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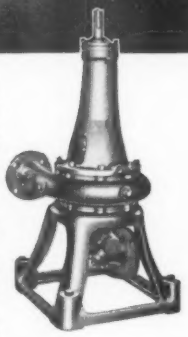
What is it? It's a plastic model of the amazing new "Bladeless" impeller developed by Fairbanks-Morse pump engineers for Figure 5400 solids-handling pumps.

Why no catch in it? Because, unlike conventional impellers, there are no blades to catch and hold fibrous trash. It makes possible a truly "non-clog" pump. The chain in the illustration follows the water path through the single channel impeller and shows clearly that there's no "catch" possible. And that's important from a maintenance and operating cost angle because the ordinary solids-handling pump often must be dismantled as much as twice daily to clear clogged impellers.

This new advance in pump design is typical of the constant research and product improvement that make possible the high quality and efficient performance of all Fairbanks-Morse products. Fairbanks, Morse & Co., 600 South Michigan Avenue, Chicago 5, Illinois



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Fairbanks-Morse Figure 5400 solids-handling pump, featuring the "single channel" impeller. Phantom view of impeller clearly shows that there are no "blades" to catch or damage pumped material.

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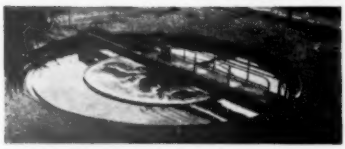
PROCESS CLARIFIERS

Above is pictured a type C primary Clarifier, 70 ft. diameter circular tank with rotating skimmer designed for the Indio Sanitary District of Indio, California. Engineers: Koebig & Koebig. Contractor: Kelley Construction Co. This rugged, built-to-last, trouble free Clarifier is another typical example of a "Process Engineers Inc." successful installation.

PROCESS OXIDATORS

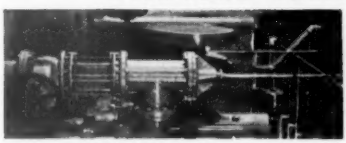


Process Oxidators include aeration, coagulation and sedimentation in a single circular tank giving the results of intermediate treatment at practically the cost of primary treatment. Installations mean lower initial expenditure, higher efficiency in operation and reduced maintenance cost.

PROCESS AUTOMATIC *Variable Level* SKIMMERS

This device automatically skims floating material from the surface of a liquid that varies in elevation by several feet. The difference in elevation between the liquid level and the lip for skimmings is adjustable and will maintain this adjustment during the up and down travel. The device is sensitive within ¼" change in the liquid level.

PROCESS CLEANABLE SIGHT GLASS



A short section of special glass inserted in the piping system to make the contents visible to the operator. Applicable to sludge lines, supernatant liquor and other applications where it is desired to easily observe the character of the material being handled.

For complete information without obligation regarding any of the equipment described, communicate with any of the addresses listed below.

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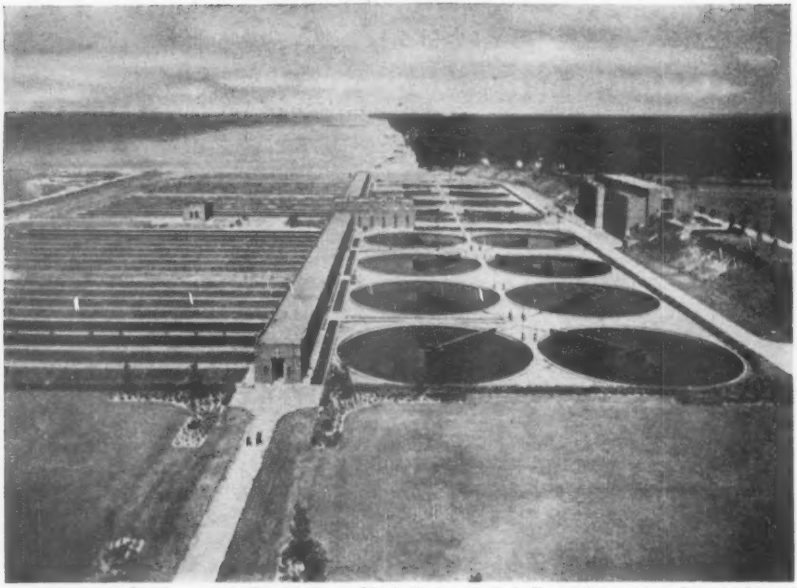

Information courtesy Cleveland Dept. of Public Works—Mr. G. E. Flower, Commissioner of Sewage Disposal.

Cleveland's Easterly sewage plant uses ALOXITE diffusers

The well cared for park-like area you see from Lake Shore Blvd. in Cleveland, opposite East 140th St., is actually part of this large Easterly Sewage Treatment Plant. Looking along the lake shore here, the aeration tanks, galleries, etc., can be seen to the left.

This modern plant uses the air diffusion process, employing ALOXITE aluminum oxide diffusers. This type of aeration gives the high degree of treatment—at low cost—essential to a densely populated area. It affords the necessary protection for Cleveland's water supply and bathing beaches. And it provides odor control which, of course, is vitally important.

The ALOXITE porous plates in this plant have been in service for a number of years, and have proved most satisfactory.

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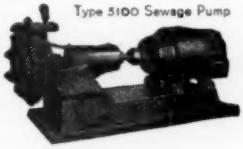
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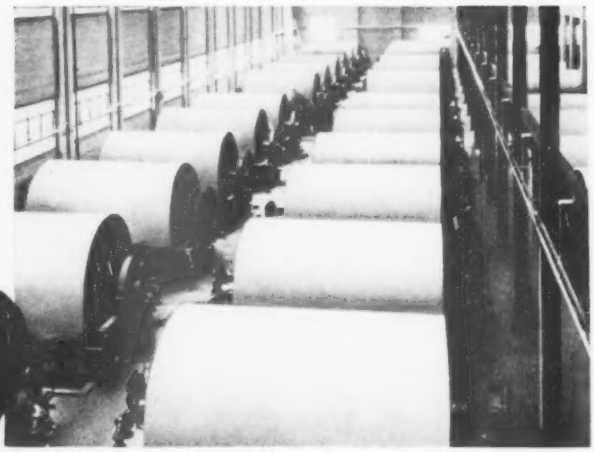

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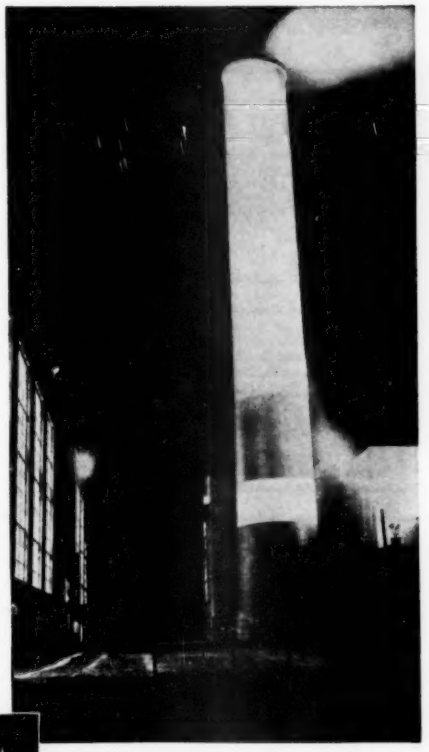

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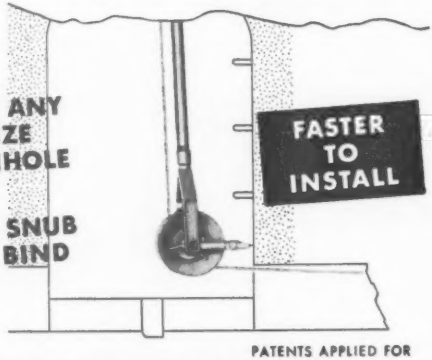

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